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### 2018 Sound Transit Standard Specifications

#### Revision Record

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This 2018 edition of the Sound Transit Standard Specifications has been developed to serve as the baseline for delivering and designing the projects for the public by Sound Transit. The Standard Specifications, unless otherwise stated in writing, will be incorporated into the Contract Documents, except where specifically excluded. The decision to exclude, modify or replace any standard specification is made during the design process and is subject to approval by Sound Transit.

While these specifications are to be used as a baseline during the design process, once they have been incorporated into the Contract Documents they become material and enforceable terms of that Contract. Following the completion of Issue For Bid or Issue For Construction documents, these Standard Specifications are subject to revision only through the change order process.
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies demolition, removal, and disposal of surface and subsurface structures, and related ancillary components. Work shall include removal and disposal of all existing materials and equipment as indicated on the Contract Drawings and as needed for a complete installation of all improvements. Variations shall be reported to the Resident Engineer.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:
1. Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)
2. Standard plans and specifications of Authority Having Jurisdiction (AHJ)

B. Definitions

1. Structure: Facilities including but not limited to buildings, bridges, walls, slabs, beams, foundations, footings, piles, foundation systems, pavements, curbs and ramps, loading docks, stairs, canopies, and sidewalks.
2. Asphalt Concrete Pavements: Streets, driveways, alleyways, or other surfaces constructed from bituminous mix, or any combination of bituminous mixes or surface treatments.
3. Concrete Pavements: Streets, driveways, alleyways, or other slabs greater than six inches in thickness, constructed from Portland Cement Concrete, including those constructed with or without an asphaltic overlay.
4. Concrete Sidewalks: Concrete slabs six inches or less in thickness, with or without asphaltic overlay.

1.03 SUBMITTALS

A. Demolition and Removal Construction Work Plan
1. Waste Management Plan
2. Waste Management Progress Reports

B. Permits
1. Demolition
2. Hauling and debris disposal
3. Groundwater discharge
4. Historical designation
C. Utility Severance Certificates

D. Rodent Control Inspection and Extermination Statement: As described in Article 3.02 herein

E. Letter verifying re-establishment of survey markers and monuments, signed by a land surveyor licensed in the State of Washington

F. Private Property Owner’s Release: If material demolished and removed from the site will be deposited on private property, two copies of written releases shall be submitted to Resident Engineer. Releases shall absolve Sound Transit from responsibility concerning the depositing of material on private property, and releases shall be signed by the owners of property on which the material will be deposited.

1.04 DEMOLITION AND REMOVAL CONSTRUCTION WORK PLAN

A. Work Plan shall include the following:

1. Demolition schedule, including timing for utility disconnects and durations of parking lot or roadway and traffic impacts

2. As-Built Drawing(s) of surveyed locations and depths of disconnected utilities, walls, and foundations left on site

3. Description and shop drawings of method and sequence of demolition and removal for all stages

4. Description of equipment types to be used in all demolition and removal operations

5. Description of method and equipment to be used for containment, collection, and salvage, recycling, or disposal of all debris

6. Description of haul routes and access points

7. Field measurements of items and members of the existing structure prior to preparing shop drawings for concrete elements

8. Plans and calculations for false works, prepared by a registered Professional Engineer in the State of Washington, to be used for the existing and new structures

9. Temporary storage location for rail scheduled to be removed or reused as guardrail

10. Description of cleanup methods

11. Waste Management Plan in accordance with Section 01 74 00 Cleaning and Waste Management

1.05 SITE CONDITIONS

A. The Contract Drawings are produced from original contract drawings and field observations. Drawings may not fully represent an accurate as-built condition. Drawings of existing conditions are for Contractor’s general reference and orientation. Discrepancies may be encountered, and it shall be the Contractor’s responsibility to carefully examine and field verify all conditions, including extent of materials remaining in buildings on site.
B. Surveys and potholes shall be performed to locate existing drainage and utilities. Drawings shall be prepared to depict existing utilities. Existing utilities and drainage to remain shall be protected from damage.

C. Existing structures and utilities may contain asbestos, lead, PCB or mercury. Hazardous Material-related work is not included in the scope of this Section.

D. Prior to beginning demolition, Contractor shall make a complete inspection of the project conditions, including existing visible defects. Visible defects shall be photographed and logged by the Contractor and verified by the Resident Engineer.

E. It is solely the Contractor’s responsibility to determine demolition procedures and sequences to ensure the safety of operation. This may include the use of temporary shoring or bracing. If during demolition, damages are made to structures or utilities, repair and restoration shall be promptly performed by the Contractor at no cost to owner.

F. At completion of demolition, the Contractor shall make examination of exposed components and possible damage caused by demolition work. Examination report shall be submitted to Resident Engineer for approval.

G. Except for items indicated for salvage or reuse, material removed shall become the Contractor’s property and shall be removed from the Site before completion of project.

1.06 PROTECTION AND SECURITY

A. Attention and protection shall be given to existing structures, utilities, and equipment that are to remain.

B. Security of existing facilities shall be maintained.

PART 2 - PRODUCTS

2.01 MATERIALS, EQUIPMENT, AND FACILITIES

A. Products for patching, extending, and matching shall be the same types as those used in existing facility, and in accordance with AHJ requirements.

PART 3 - EXECUTION

3.01 GENERAL

A. Obtain required permits and licenses. Give required notices for performance and completion of demolition, removal, hauling, disposal of debris, and other permit requirements identified in this Section.

B. Install temporary chain link fencing to secure all work areas, as indicated on Contract documents.

C. Perform demolition in accordance with the approved Demolition and Removal Construction Work Plan. Use methods within limitations of governing regulations. Demolition shall be done safely and shall avoid damaging any portions of the Structure that are to remain. Federal, local and state codes, including WAC 296-155 “Safety Standards for Construction Work”, Part S “Demolition”, shall be observed at all times. The Contractor shall review all Drawings of the existing Structure noted in the Contract.

D. Exercise pollution controls as specified in Contract documents.
E. Remove trees, shrubs, and other vegetation within construction limits, except those identified to be protected in the Contract documents.

F. Protect trees and shrubs outside of construction limits and street trees within construction limits.

G. Demolish and remove existing construction only to the extent required by Contract Drawings.

H. Cut demolition lines and openings true to dimensions required. Use cutting methods that minimizes damage and disturbance to remaining construction. Provide temporary covers over openings.

I. Cut or drill from the exposed or finished side into concealed surfaces to avoid marring existing finished surfaces.

J. Do not use cutting torches until work area is cleared of flammable materials. Verify condition and contents within concealed spaces, such as ducts and pipes, before starting flame-cutting operations. Maintain ventilation and keep portable fire-suppression devices nearby, during flame-cutting operations.

K. Do not use explosives.

L. Remove and lower framing members to ground, by means to prevent free fall, ground impact, and dust generation.

M. Avoid overloading existing construction, when placing demolition equipment and removing debris.

N. Completely fill abandoned pipes with Controlled Density Fill (CDF) in accordance with AHJ and manufacturer requirements. CDF shall meet the requirements of WSDOT Standard Specifications for Road, Bridge and Municipal Construction.

O. Abandon catch basins, valve chambers, manholes and inlets as shown on the plans in accordance with AHJ and WSDOT Standard Spec Section 7-05.3(2).

P. When hazardous materials are encountered during demolition operations, comply with applicable regulations, laws, and ordinances concerning removal, handling, disposal, and protection against exposure to environmental pollution.

3.02 RODENT CONTROL INSPECTION AND EXTERMINATION

A. Secure a registered sanitarian in the State of Washington to conduct a survey for evidence of current rodent activity.

B. Initiate a control program by a health department certified pest control operator, if the survey indicates that it is necessary. The control program shall include the following minimum requirements:

1. At least 10 days before demolition begins, purge the work area of rodents and prevent their migration to adjacent areas. Maintain rodent-free state for three months. As directed by the Resident Engineer, execute rodent control and extermination within a one-block radius of the work area, with the permission of property owners or tenants.

2. Place toxic bait in the form of one pound paraffinized block, in each manhole or storm drain inlet located on the same street as the facility (to be demolished), as well as at its closest intersection(s). Additional baits may be placed, as determined by the pest control operator.
3. Where there is no competing water supply, liquid anticoagulant baits may be used at the discretion of the certified pesticide applicator.

4. Inspect toxic baits and renew as necessary on the fourth or fifth day after initial baiting, and every seven days thereafter.

5. Remove and dispose of rodent carcasses in sealed plastic bags.

6. Submit a statement signed by the pest control operator, after the initial treatment. For each follow-up inspection, report the types and amount of baits placed in each location; state the visible results obtained from the rodent control program.

7. Remove bait blocks upon completion of project.

3.03 SALVAGE

A. Sound Transit has performed salvage of limited landscaping materials and building interior materials such as trim, interior doors, appliances, plumbing fixtures and light fixtures prior to Notice to Proceed for this Contract. Salvage operations were performed under a separate contract with Sound Transit. Any items remaining in the buildings are to be removed as part of the demolition work. Remaining items can be viewed at the prebid site walk through.

B. Additional items that may be removed for salvage prior to demolition include the following:

1. Copper
2. Glu-lam beams
3. Vertical timbers
4. Wood decking
5. Structural beams
6. Porch columns
7. Exterior windows
8. Vinyl windows
9. Exterior doors
10. Granite
11. Brick
12. Elevator equipment

3.04 PROTECTION

A. General

1. Protect remaining work and adjacent facilities from damage. Do not interfere with neighboring buildings, facilities, or activities.

2. Perform demolition by means that protect the public, workers, and existing materials.
3. Provide bracing and shoring to maintain the stability of existing facilities and construction.

4. Provide barriers, safety guards, and warning lights near openings and depressions. Operate warning lights from dusk to dawn daily.

5. Provide environmental protection as required by the State of Washington to prevent refuse and waste from entering waterways or utility drains.

B. Preservation of Reference Markers

1. Record the locations and designation of survey markers and monuments, prior to their removal. Provide three reference points for each survey marker and monument removed. Reference points shall be established by a land surveyor licensed in the State of Washington.

2. Store removed markers and monuments during demolition work. Replace and re-establish survey markers and monuments in conformance with the recorded reference points, upon completion of work.

C. Protection of Utilities

1. Protect utilities and pavements from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by the demolition operations.

2. Arrange for and verify temporary termination of utility services encountered and as indicated on the Contract Drawings, in conformance with AHJ.

3. If utility is damaged, immediately notify the Resident Engineer and the utility owner for corrective action.

3.05 DISPOSAL OF DEMOLISHED MATERIALS

A. Except for items or materials indicated in the Waste Management Plan to be reused, salvaged, recycled, reinstalled, or otherwise indicated to remain Sound Transit's property, the Contractor shall remove and transport demolished materials from Work site and legally dispose.

1. Do not allow demolished materials, including those to be salvaged, recycled, or disposed to accumulate on site. Remove materials from building and work site regularly, so their presence will not create hazardous conditions for workers and the public.

2. Comply with AHJ requirements over handling, removal, hauling, and disposal of materials.


4. Do not burn or bury materials.

3.06 REPLACEMENT AND RESTORATION

A. When non-scheduled items are demolished or removed, items shall be replaced as directed by the Resident Engineering.

B. Repair and restore damaged facilities, caused by demolition and operation, to their original conditions or better.
C. Backfill and level depressions caused by demolition and operation. Grade ground surface as indicated on Contract Drawings and eliminate water pockets.

D. Remove temporary chain link fencing, barriers, and safety guards upon completion of work.

3.07 CLEANING

A. Maintain a clean and orderly work site.

B. Clean adjacent facilities; remove dust, dirt, and debris caused by demolition operations. Return adjacent facilities to previously existing or better condition, prior to demolition operations.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies requirements for materials, proportioning, production and delivery of Portland cement concrete.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Concrete Institute (ACI)
   a. ACI 121R Quality Management System for Concrete Construction
   b. ACI 211.1 Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete
   c. ACI 301 Standard Specifications for Structural Concrete
   d. ACI 304R Guide for Measuring, Mixing, Transporting and Placing Concrete
   e. ACI 304.2R Placing Concrete by Pumping Methods
   f. ACI 305R Guide to Hot Weather Concreting
   g. ACI 306.1 Standard Specification for Cold Weather Concreting
   h. ACI 318 Building Code Requirements for Structural Concrete

   a. ASTM C33 Standard Specification for Concrete Aggregates
   b. ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
   c. ASTM C40 Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
   d. ASTM C88 Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
   e. ASTM C94 Standard Specification for Ready-Mixed Concrete
   f. ASTM C114 Standard Test Methods for Chemical Analysis of Hydraulic Cement
   g. ASTM C127 Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Coarse Aggregate
h. ASTM C128 Standard Test Method for Density, Relative Density (Specific Gravity) and Absorption of Fine Aggregate
i. ASTM C131 Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
k. ASTM C150 Standard Specification for Portland Cement
m. ASTM C260 Standard Specification for Air-Entraining Admixtures for Concrete
n. ASTM C289 Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
o. ASTM C494 Standard Specification for Chemical Admixtures for Concrete
q. ASTM C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
r. ASTM C989 Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
s. ASTM C1017 Standard Specification for Chemical Admixtures for Use in Producing Flowing Concrete
t. ASTM C1116 Standard Specification for Fiber-Reinforced Concrete
u. ASTM C1240 Standard Specification for Silica Fume Used in Cementitious Mixtures
v. ASTM C1602 Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
w. ASTM E329 Standard Specification for Agencies Engaged in Construction Inspection and/or Testing

3. City of Seattle (COS)

a. Standard Specifications for Road, Bridge and Municipal Construction

1.03 DEFINITIONS

A. Concrete Mix: Concrete mixes are defined in the contract documents. Each mix is designated to have one or more uses. Furnish a separate mix design for each concrete mix.

B. Mass Concrete: Section 03 30 00, Cast-In-Place Concrete.
D. Total Cementitious Materials: The amount of Portland cement plus the amount of all supplementary cementitious materials.
E. W/CM Ratio: The ratio of water to total cementitious materials by weight.

1.04 SUBMITTALS
A. Concrete Mix Designs: For each concrete mix submit a concrete mix design. Include the following as a minimum:
   1. Supplier, mix design number, and plant location.
   2. Proposed use.
   3. Mix constituents, including:
      a. Cement: Supplier, source, type, and specific gravity.
      b. Supplementary Cementitious Materials: Supplier; source; type, class or grade; and specific gravity.
      c. Coarse Aggregate: Supplier, source, grading, type, and specific gravity.
      d. Fine Aggregate: Supplier, source, grading, type, and specific gravity.
      e. Admixtures: Manufacturer, product, and type.
      f. Micro synthetic, macro synthetic, and steel fibers
      g. Water: Source of supply.
   4. Mix constituent proportions per cubic yard, including weight or dose and absolute volume.
   5. Mix constituent ratios, including water to total cementitious material ratio by weight and Supplemental cementitious material to total cementitious material ratio by weight
   6. Concrete mix properties, including:
      a. 28-day or 56-day compressive strength, as applicable
      b. Unit weight
      c. Slump
      d. Percent entrained air
   7. Statistical analysis determining the required average compressive strength in conformance with ACI 301.
   8. Documentation of average compressive strength in conformance with ACI 301.
      a. If field test data are used, all data shall be supported by an Independent Testing Laboratory's reports.

B. Transmit: Admixtures: For each admixture, submit the following:
   1. Manufacturer’s product data showing conformance with this Section.
2. Manufacturer’s published instructions for storage, handling, and use.
3. Material Safety and Data Sheets, when available.
4. Manufacturer’s certification that admixture is compatible with all other admixtures used in the mix design.

C. Transmit: Micro synthetic, macro synthetic, and steel fibers
   1. Manufacturer’s product data showing conformance with this Section.
   2. Manufacturer’s published instructions for storage, handling, and use.
   3. Material Safety and Data Sheets, when available.

D. Transmit: Material Certification
   1. For each material, submit supplier’s certification that the materials conform to the requirements of this Section.

E. Transmit: Qualifications:
   1. Concrete supplier.
   2. Independent Testing Laboratory.

F. Concrete Quality Program Plan: Conform to contract documents

G. Transmit: Concrete Mix Environmental Product Declaration (EPD)
   1. For a minimum of 75% by volume of the cast-in-place concrete mix designs, transmit Environmental Product Declarations in accordance with The Carbon Leadership Forum Product Category Rules (PCR) for ISO 14025 Type III Environmental Product Declarations (EPDs) for Concrete.
   2. Calculate the NRMCA Pacific Northwest Region Benchmark average Global Warming Potential (GWP) for the volume of concrete with EPDs. The calculation shall include:
      a. A list of all classes of concrete used in the project. A class of concrete is determined by the 28-day compressive strength (i.e. 3000 psi concrete, 4000 psi concrete).
      b. A list of the projected volume of each class of concrete to be used in the project. The total volume reported shall match the total volume of concrete listed in the Proposed Mix Design average GWP calculations.
      c. A list of the GWP for each class of concrete for the Pacific Northwest Region as reported in the NRMCA Member National and Regional Life Cycle Assessment Benchmark (Industry Average) Report, dated October 2014. These regional averages are as follows:
<table>
<thead>
<tr>
<th>Indicator / LCI Metric Unit (equivalent)</th>
<th>Global Warming Potential (GWP) kg CO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2500 psi Concrete per yd³</td>
<td>199.92</td>
</tr>
<tr>
<td>3000 psi Concrete per yd³</td>
<td>222.58</td>
</tr>
<tr>
<td>4000 psi Concrete per yd³</td>
<td>272.33</td>
</tr>
<tr>
<td>5000 psi Concrete per yd³</td>
<td>336.67</td>
</tr>
<tr>
<td>6000 psi Concrete per yd³</td>
<td>354.66</td>
</tr>
<tr>
<td>8000 psi Concrete per yd³</td>
<td>432.99</td>
</tr>
</tbody>
</table>

Interpolation is permitted to determine GWP values for concrete classes between the values shown in the table.

Where a concrete class has a lower 28-day strength than 2500 psi the following equations shall be used to determine the Benchmark GWP:

\[
GWP = 199.92 - [2500 \text{ psi} - \text{28-day strength (psi)}] \times 0.045 \text{ per yd}^3
\]

Where a concrete class has a higher 28-day strength than 8000 psi the following equations shall be used to determine the Benchmark GWP:

\[
GWP = 432.99 + (28\text{-day strength (psi)} - 8000 \text{ psi}) \times 0.039 \text{ per yd}^3
\]

d. Calculate the weighted average NRMCA Pacific Northwest Region Benchmark GWP for the volume of concrete corresponding to the Proposed Mix Designs with EPDs as follows:

\[
\text{GWP}^\text{AVG} = \frac{\sum_{i=1}^{n} [GWP_i \times Volume_i]}{\sum_{i=1}^{n} Volume_i}
\]

Where:

- \(GWP_i\) = global warming potential for concrete class \(i\)
- \(Volume_i\) = projected volume of concrete for concrete class \(i\)
- \(n\) = total number of classes of concrete

3. Calculate the weighted average Proposed Mix Design GWP for the volume of concrete with EPDs. The calculation shall include:

a. A list of all mixes proposed to be used on the project. This list shall include the supplier, mix design number, supply plant location, EPD Program Operator, EPD Developer, EPD issue date, and EPD expiration date for every mix.
b. A list of the projected volume of each mix to be used on the project. The total volume reported shall match the total volume of concrete listed in the NRMCA Pacific Northwest Region Benchmark average GWP calculations.

c. A list of GWP, as shown on the mix's EPD, for each proposed mix.

d. Calculate the Proposed Mix Design average GWP as follows:

\[
GWP_{\text{AVG}} = \frac{\sum_{i=1}^{n} [GWP_i \times Volume_i]}{\sum_{i=1}^{n} Volume_i}
\]

Where:

- GWP\(_i\) = global warming potential for proposed mix \(i\)
- Volume\(_i\) = projected volume of concrete for proposed mix \(i\)
- \(n\) = total number of proposed mixes of concrete

4. Calculate the percent reduction in Proposed Mix Design average GWP as compared to the NRMCA Pacific Northwest Region Benchmark average GWP.

### 1.05 QUALITY ASSURANCE

A. Concrete Supplier: Select a concrete supplier holding a current Certificate of Conformance for Concrete Production Facilities from the National Ready Mix Concrete Association.

B. Concrete Quality Program Plan: Develop a Quality Program Plan in conformance with the recommendations of ACI 121R.

### 1.06 DELIVERY, STORAGE, AND HANDLING

A. Cementitious Materials: Store in dry, weather-tight buildings, bins, or silos that exclude contaminants.

B. Coarse and Fine Aggregates: Store to prevent segregation and contamination from other materials or other gradations or types of aggregate. Store to drain freely. Do not use frozen aggregate.

C. Admixtures: Store and handle in conformance with manufacturer's published instructions.

D. Micro synthetic, macro synthetic, and steel fibers: Store and handle in conformance with manufacturer's published instructions.

E. Water: Protect from contamination.

### PART 2 - PRODUCTS

#### 2.01 MATERIALS

A. General: For each material:
1. Use only one source in each mix design.

2. If source changes, submit a revised mix design using the product from the new source.

3. Do not change source for an approved mix design without written approval by Resident Engineer.

B. Cementitious Materials


2. Supplementary Cementitious Materials
   c. Silica Fume: ASTM C1240

C. Coarse Aggregate

1. Hard, strong, durable gravel or crushed stone conforming to ASTM C33.

2. Grading:
   a. City of Seattle: COS Standard Specification Section 9-03.1(3) D.
   b. WSDOT and outside City of Seattle: WSDOT Standard Specifications Section 9-03.1(2)B

3. Use only aggregate that is innocuous with work.

4. Meet the following requirements when tested in conformance with the specified test methods:
   a. Resistance to Abrasion (ASTM C131): For the loss for aggregate size range 3/4-inch to 3/16-inch after 100 revolutions and 500 revolutions do not exceed 10 percent and 35 percent, respectively. Include within the test sample seven parts of Grading B and three parts of Grading C.
   b. Resistance to Abrasion (ASTM C535): For the loss for aggregate size range 1-1/2 inches to 3/4 inch (Grading 3) after 200 revolutions and 1,000 revolutions do not exceed 10 percent and 35 percent, respectively.
   c. Soundness (ASTM C88): Weighted average loss after 5 cycles not to exceed 10 percent when tested with sodium sulfate.
   d. Bulk Specific Gravity (ASTM C127): On the basis of saturated surface-dry aggregate not less than 2.60.
   e. Absorption (ASTM C127): Not to exceed 3 percent.
   f. Potential Reactivity (ASTM C289): Only use aggregates that are not harmful for Cement-Aggregate Alkali reactivity.
   g. Potential Reactivity (ASTM C227): Only use aggregates that are not harmful for Cement-Aggregate Alkali reactivity.

D. Fine Aggregate
1. Hard, strong, durable stone or rock fragments conforming to ASTM C33, except as modified herein.

2. Grading:
   a. City of Seattle: COS Standard Specification Section 9-03.1(3) D.
   b. WSDOT and outside City of Seattle: WSDOT Standard Specifications Section 9-03.1(2)B

3. Use only aggregate that is innocuous with work.

4. Meet the following requirements when tested in conformance with the specified test methods:
   a. Soundness (ASTM C88): Weighted average loss after 5 cycles not to exceed 10 percent when tested with sodium sulfate.
   b. Bulk Specific Gravity (ASTM C128): On the basis of saturated surface-dry aggregate not less than 2.60.
   c. Organic Impurities (ASTM C40): Supernatant liquid lighter in color than the reference standard color solution
   d. Fineness Modulus (ASTM C33): In the range of 2.80 to 3.50; for the fine aggregate not to vary more than plus or minus 0.20 from the fineness modulus of the fine aggregates used in the concrete mix design.
   e. Absorption (ASTM C128): Not to exceed three percent.
   f. Potential Reactivity (ASTM C289): Only use aggregates that are not harmful for Cement-Aggregate Alkali reactivity.
   g. Potential Reactivity (ASTM C227): Only use aggregates that are not harmful for Cement-Aggregate Alkali reactivity.

E. Admixtures

1. General
   a. Do not use admixtures containing chlorides, sulfides, or nitrides.
   b. Provide admixtures compatible with all other admixtures used in the concrete mix.


3. Chemical Admixtures:
   a. Water-Reducing: ASTM C494, Type A.
   b. High Range, Water Reducing: ASTM C494, Type F.
   c. Plasticizing and Retarding: ASTM C1017, Type II.

F. Micro synthetic, macro synthetic, and steel fibers: Complying with ASTM C 1116.

2.02 MIX DESIGNS

A. Obtain concrete mix designs from a qualified Independent Inspection Laboratory or concrete supplier properly equipped to design concrete mixes.

B. Select mix proportions in conformance with ACI 211.1.

C. Design concrete mixes intended for pumping in conformance with the recommendations of ACI 304R and ACI 304.2R.

D. If trial batch data are used, sample and test concrete in conformance with Section 03 30 00 Cast-In-Place Concrete.

E. Establish proportions of materials for each concrete mix to:
   1. Provide workability and consistency to permit concrete to be worked readily into forms and around reinforcement under conditions of placement to be employed, without segregation or bleeding.
   2. Meet the strength and applicable exposure requirements in the contract documents.

F. Aggregate Size: Nominal size of coarse aggregate shall not be larger than the least of:
   1. 1/5 the narrowest dimension between the sides of the forms.
   2. 1/3 the depth of slabs.
   3. 3/4 the minimum clear spacing between individual reinforcing bars or wires, or bundles of bars.

G. Slump: Establish consistency of concrete to facilitate placement with minimized potential for segregation.

2.03 SOURCE QUALITY CONTROL

A. Sample Tests and Analyses: Test cement, coarse aggregate and fine aggregate to demonstrate conformance with the following requirements:
   2. Aggregates:
      a. Grading and quality: City of Seattle Specification, Section 9-03.1
      b. Sieve analysis: ASTM C136

PART 3 - EXECUTION

3.01 MEASURING, BATCHING, AND MIXING

A. Measure, batch, and mix Portland cement concrete in conformance with ASTM C94.
   1. Use central-mixed concrete transported to the jobsite in truck mixers.
   2. Use truck mixers equipped with:
      a. Automatic device for recording the number of drum revolutions prior to completion of mixing operations.
b. Either accurately calibrated water tanks or water meters.

3.02 DELIVERY

A. Transport and deliver concrete in conformance with ASTM C94 and furnish batch ticket information.

1. Batch tickets shall include the amount of water in the batch from the plant and the remaining water that may be added at the site, if any.

B. Mix concrete continuously in truck mixer until discharged.

C. Mix ready-mixed concrete for a period of not less than 10 minutes. Mix for at least 3 minutes immediately prior to discharging at the site.

D. Do not place concrete more than 90 minutes or 300 drum revolutions after introduction of the mixing water, whichever is less.

3.03 SLUMP ADJUSTMENT AT THE SITE

A. If concrete arrives at the site with a slump less than is workable for the given mix design, the slump may be adjusted by adding water at the site with the following restrictions:

1. Water added at the site was withheld from the batch water at the plant.

2. The total water added at the plant and the site does not exceed the mix design water amount.

3. Water is added at the site in conformance with ASTM C94.

B. Do not add water to the concrete after water reducing admixtures are added at the site.

C. Do not add water to the concrete after partial discharge of the load.

D. Retest slump, temperature, and air content after slump adjustment in conformance with Section 03 30 00 Cast-In-Place Concrete.

3.04 WEATHER RELATED PLACEMENT

A. Refer to 03 30 00 Cast-In-Place Concrete

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. This Section includes requirements for the design, construction, and treatment of formwork for cast-in-place concrete construction.

1.02 REFERENCES
   A. Definitions
      1. Roughened: Concrete intentionally roughened to a full amplitude of approximately 1/4 inch.
      2. With the above exception, the words and terms used in this Section conform to the definitions given in ACI 116R.
   B. This Section incorporates by reference the latest revisions of the following documents.
      1. American Concrete Institute (ACI)
         a. ACI 116R Cement and Concrete Terminology
         b. ACI 117 Standard Specification for Tolerances for Concrete Construction and Materials
         c. ACI 301 Specifications for Structural Concrete
         d. ACI 347R Guide to Formwork for Concrete
      2. American Plywood Association (APA)
         a. PS 1 U.S. Product Standard for Construction and Industrial Plywood
         b. Design/Construction Guide: Concrete Forming
      3. American Society for Testing and Materials International (ASTM)
         a. ASTM D994 Standard Specification for Preformed Expansion Joint Filler for Concrete (Bituminous Type)
         b. ASTM D1751 Standard Specification for Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
         c. ASTM D4397 Standard Specification for Polyethylene Sheeting for Construction, Industrial, and Agricultural Applications
      4. Federal Specifications (FED)
         a. FED TT-S-1543B Sealing Compound: Silicone Rubber Base (For Caulking, Sealing, and Glazing in Buildings and Other Structures)
5. West Coast Lumber Inspection Bureau (WCLIB)
   a. WCLIB No. 17 Standard Grading Rules

6. Washington State Department of Transportation (WSDOT)
   a. WSDOT Standard Specifications for Road, Bridge and Municipal Construction

1.03 SUBMITTALS

A. Transmit: Samples
   1. Formwork facing materials: One sample for each type used, minimum of 12 inches by 12 inches or large enough to demonstrate conformance with the required formed pattern.

B. Transmit: Manufactured Products:
   1. For formliners:
      a. Manufacturer’s Product Data to demonstrate conformance.
      b. Manufacturer’s written instructions for storage, handling, and installation.

C. Shop Drawings:
   1. Overall geometry of formwork, shoring, reshoring, and backshoring.
   2. Locations and details of:
      a. Expansion joints and construction joints.
      b. Maximum lift height, maximum pour length, maximum pour rate.
      c. Formed concrete items such as keys, blockouts, and openings.
      d. Embedded items such as metal fabrications, waterstops, and conduit
      e. Form ties (if used). Layout of form ties shall reinforce the architectural design. Hole Plugs shall be used per specification.
      f. Control Joints to control and direct shrinkage cracking. Submit joint plan for approval prior to pouring slabs and walls.
      g. Corner chamfers

3. Procedures for:
   a. Erecting formwork and shoring.
   b. Monitoring formwork movement during concrete placement.
   c. Determining strength of concrete for removal of formwork if other than field-cured cylinders.
   d. Removing formwork, reshoring, and backshoring.

D. Calculations, sealed by a professional engineer. Include working drawings describing the formwork, shoring, geometry, details, and procedures.

E. Transmit: Qualifications for professional engineer.
F. Formwork Construction Work Plan. Construction Work Plan shall include complete details, drawings, a step-by-step procedure, and shall provide the anticipated time for each construction activity.

1.04 QUALITY ASSURANCE
   A. Professional Engineer: Select a licensed professional engineer currently registered in the State of Washington with minimum 5-year experience in this type of design.

1.05 DELIVERY, STORAGE AND HANDLING
   A. Store and handle form facing materials to prevent distortion, damage, and contamination that could adversely affect the concrete finish.
   B. Store and handle manufactured products in conformance with manufacturer’s written instructions.

1.06 PROJECT CONDITIONS
   A. Allow sufficient time between erection of forms and placing of concrete for the various trades to properly install concrete reinforcement, embedded items, sleeves, and blockouts.
   B. Do not apply lateral or vertical superimposed loads to structure until concrete has developed specified compressive strength.

1.07 CONSTRUCTION WORK PLAN FOR WORK OVER TRAFFIC
   A. Construction Work Plan for work over traffic shall include the proposed work schedule, durations, night activities, activities over traffic, precautions for work performed over traffic, and any sidewalk, lane, shoulder or roadway closures needed to perform the work. The work plan shall also include the drainage plan.
   B. Complete details of the catchment structure for protection of traffic. The catchment structure details shall include horizontal and vertical clearances to sidewalks or roadways open to traffic during construction of each cast-in-place element.

PART 2 - PRODUCTS

2.01 DESIGN REQUIREMENTS
   A. Design and installation of formwork shall conform to ACI 301.
   B. Plywood for formwork shall be designed in accordance with the APA Design/Construction Guide: Concrete Forming.
   C. Design formwork, shores, reshores, and backshores in conformance with the recommendations of ACI 347R.
   D. Design formwork and shores to resist pressure resulting from and maintain tolerances during placement and vibration of concrete.
   E. Design formwork to be removed without damage to adjacent concrete surfaces or materials.
   F. For post-tensioned Structures, formwork shall be designed to carry the additional loads caused by the post-tensioning operations.
G. Do not use earth cuts as forms for vertical or sloping surfaces unless indicated on the Contract Documents.

H. Tolerances: Design and construct formwork to produce finished concrete surfaces within the following tolerances:

1. Deflection of Facing Material from dead load and concrete fluid pressure
   a. Unexposed non-visible surfaces, including the bottom of deck slab between girders: L/270.

2. Vertical Alignment
   a. Lines, surfaces, and arises: 1 inch
   b. Outside corner of exposed corner columns and control joint grooves in concrete exposed to view: 1/2 inch

3. Lateral Alignment
   a. Members: 1 inch
   b. In slabs, centerline location of openings 12 inches or smaller and edge locations of larger openings: 1/2 inch
   c. Sawcuts, joints, and weakened plane embedments in slabs: 3/4 inch

4. Level Alignment
   a. Tops of slabs
      1) Elevation of slabs on grade: 3/4 inch
      2) Elevation of top surfaces of formed slabs before removal of supporting shores: 3/4 inch
      3) Slabs that receive thin-set tile or resilient flooring shall have a flatness rating of 35 and levelness rating of 25 per ACI 117.
      4) Slabs that receive carpet shall have a flatness rating of 25 and levelness rating of 20 per ACI 117.
   b. Elevation of formed surfaces before removal of shores: 3/4 inch
   c. Lintels, sills, parapets, horizontal grooves, and other lines exposed to view: 1/4 inch

5. Cross-sectional Dimensions
   a. Members, such as columns, beams, piers, walls (thickness only), and slabs (thickness only)
      1) Dimension 12 inch or less: plus 3/8 inch, minus 1/4 inch
      2) Dimension more than 12 inch but less than 3 feet: plus 1/2 inch, minus 3/8 inch
      3) Dimension over 3 feet: plus 1 inch, minus 3/4 inch
6. Relative Alignment
   a. Stairs
      1) Difference in height between adjacent risers: plus or minus 1/8 inch
      2) Difference in width between adjacent treads: plus or minus 1/4 inch
   b. Grooves
      1) Specified width 2 inches or less: plus or minus 1/8 inch
      2) Specified with more than 2 inches but less than 12 inches: plus or minus 1/4 inch
   c. Formed surfaces may slope with respect to the specified plane at a rate not to exceed 3/8 inch per 10 feet.

7. The offset between formed surface irregularities shall not exceed:
   a. Surfaces exposed to public view: ACI 117 Class A surface, 1/8 inch
   b. Other surfaces: ACI 117 Class C surface, 1/2 inch

2.02 FORM FACING MATERIALS

A. Rough Form Finish
   1. Boards: Use dressed side of lumber for surface in contact with the concrete and use dressed or tongue-and-groove edges.
   2. Framing Lumber: Structural grade, dressed or rough.

B. Smooth Form Finish
   1. Types
   2. Thickness: As required to maintain surface smoothness without deflection, but not thinner than 5/8 inch.

C. Finish Tolerance: ACI 117, including offsets at Class 'A', or better.
2.03 MANUFACTURED PRODUCTS

A. Steel Forms: Proprietary, patented, or fabricated steel forms, using standard commercial quality, uncoated steel sheet or plate, 3/16-inch minimum thickness, for panel facings. Include panel framing, reinforcement, and erection accessories.

B. Round Column Forms: Pressed or molded fiber-reinforced plastic, manufactured round column forms, seamless or one-piece (one vertical seam), smooth surface, of sizes indicated.

C. Formliners for Exposed Concrete: Thermally formed, pressed or molded fiber-reinforced plastic (FRP), acrylonitrile butadiene styrene (ABS) alloy plastic, polyvinyl chloride (PVC) configuration, and surface texture indicated. Provide formliners with natural form-release surface. Formliners may be manufactured for single-use or multi-use service as appropriate.

D. Formwork Accessories

1. Form Ties: Rod type with end fasteners which can be removed without spalling the concrete. Provide cones with setbacks equal to the required concrete cover. Form ties are not allowed for single-sided formed walls requiring waterproofing.

2. Form Tie Hole Plugs: Preformed mortar plugs to match the color of the concrete, recessed 1/4 inch. Adhere with a manufacturer approved epoxy adhesive.

3. Chamfer Strips: Fillet milled from clear, straight-grain pine, surfaced each side; or extruded vinyl type with or without nailing flange.

4. Polyethylene Sheeting: Single ply 6-mil polyethylene sheeting conforming to ASTM D4397. Provide a compatible tape with equal or better water vapor control characteristics than sheeting.

E. Form Release Agent

1. Commercial formulation, silicone-free, designed for use on all form facing materials used, which will not:
   a. Bond with, stain, or adversely affect concrete surfaces
   b. Impair subsequent treatment of concrete surfaces requiring bond or adhesion
   c. Impede wetting of surfaces which will be cured with water, steam, or curing compounds.

F. Joint and Seam Sealer: Capable of producing flush, watertight, and nonabsorbent surfaces and joints and compatible with forming material and concrete ingredients.


2. Form Film Tape: Polypropylene plastic treated with waterproof adhesive for joint conditions not exposed to public view.


2.04 SPECIAL SECTIONS

A. Provide openings, offsets, sinkages, keyways, recesses, molding, rustications strips, chamfers, blocking, screed bulkheads, anchorages, embedded items, and other features.
B. Select materials and provide workmanship to achieve indicated finishes.

PART 3 - EXECUTION

3.01 PREPARATION

A. Locate and stake out all forms and establish all lines, levels, and elevations.

3.02 CONSTRUCTION

A. General

1. Construct formwork in conformance with the approved Shop Drawings to produce finished concrete surfaces as indicated and within specified tolerances.

2. Anchor formwork to shores, supporting surfaces, or members to prevent upward or lateral movement of the formwork system during concrete placement.

3. Provide runways for moving equipment. Support runways directly on formwork or structure, without resting on reinforcing steel.

4. Provide positive means of adjustment of formwork. Adjust and secure before concrete placement. Do not adjust formwork after concrete has achieved initial set.

B. Work Over Traffic

1. Forms shall be sealed to prevent leaks

2. Catchment structure shall extend beyond work zone and shall be made of rigid material

C. Form Facing Materials

1. Provide smooth form finish materials for surfaces exposed to public view.

2. Provide rough form finish materials for surfaces not exposed to public view.

D. Form Panels

1. Maintain form panels clean, smooth, and free from imperfections and distortion.

2. Arrange form panels in symmetrical patterns conforming to general lines of the structure. Unless otherwise indicated, orient panels on vertical surfaces with long dimension horizontal and make horizontal joints level and continuous. Use largest stock size practicable.

3. Make panel joints and seams mortar-tight. Install joint and seam sealers in accordance with the manufacturer's written instructions.

4. Align form panels on each side of a panel joint with fasteners common to both panels to provide a continuous concrete plane surface.

E. Construction Joints

1. At construction joints exposed to view, lap contact surface of form sheathing for flush surfaces over the hardened concrete in the previous placement by not more than 1 inch.

2. Ensure formwork is held firmly against hardened concrete to prevent offsets or loss of mortar at construction joints and to maintain a true surface.
F. Edge Forms and Bulkheads
   1. Set edge forms, bulkheads, and intermediate screeds for slabs to obtain required elevations and contours in the finished slab surface. Ensure that edge forms and screed strips are sufficient to support the screeds to be used.
   2. When formwork is cambered, set screeds to like camber to maintain required concrete thickness.
   3. Brace bulkheads to prevent warpage or displacement. Set tightly against forms to prevent loss of concrete mortar.
   4. Seal edge forms with joint and seam sealers such that neither a fin nor groove is made in the face of the cast concrete.

G. Corners: Provide 3/4 inch chamfer on all outside corners unless noted otherwise. Miter chamfer at intersections. Reentrant corners need not have fillets.

H. Embedded Items: Provide embedded items in conformance with the approved Shop Drawings. Secure to reinforcement or formwork to prevent movement during concrete placement. Fill voids with readily removable material to prevent entry of concrete.

I. Blockouts and Openings
   1. Securely wrap concrete blockouts with sheeting forming a smooth, tight-fitting surface. Overlap sheeting material at seams a minimum of six inches and tape both sides of sheeting.
   2. Provide temporary openings at the base of column and wall formwork and other locations where necessary to facilitate cleaning and inspection. Clean and inspect immediately before concrete is placed.
   3. Provide air escape holes in bottom members of blockouts in vertical forms.

J. Form Release Agent
   1. Apply form release agent in conformance with manufacturer's written instructions.
   2. Coat form contact surfaces with form release agent before reinforcement is placed.
   3. Do not allow excess form release agent material to accumulate in the forms.
   4. Do not allow excess form release agent to come into contact with surfaces to be bonded to fresh concrete such as concrete reinforcement, embedded items, and hardened concrete.
   5. Coat steel forms with non-staining, rust-preventive form release agent, or otherwise protect against rusting. Do not use rust-stained steel surfaces for forms in contact with concrete.
   6. Apply release agent to bolts and rods that are to be removed or that are to be free to move.

3.03 REMOVAL OF FORMWORK

A. Maintain formwork supporting concrete weight in place until the concrete has attained the minimum percentage of specified design compressive strength and minimum number of days specified in Table 03 11 00-A.
### TABLE 03 11 00-A – Minimum Requirements for Formwork Removal

<table>
<thead>
<tr>
<th>Structural Member or Condition</th>
<th>Minimum Compressive Strength (Percent of Minimum Design Compressive Strength)</th>
<th>Minimum Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sides of forms not supporting the concrete weight, including columns, walls, crossbeams, non-sloping box girder webs, and abutments.</td>
<td>30</td>
<td>3 days</td>
</tr>
<tr>
<td>Side forms of footings, pile caps, and shaft caps.</td>
<td>30</td>
<td>18 hours</td>
</tr>
<tr>
<td>Crossbeams, sloping box-girder webs, struts, inclined columns, inclined walls, and other forms that support the concrete weight</td>
<td>80</td>
<td>5 days</td>
</tr>
<tr>
<td>Elevated slabs or beams over 20 feet span between supports</td>
<td>90</td>
<td>14 days</td>
</tr>
<tr>
<td>Elevated slabs or beams 10 feet to 20 feet span.</td>
<td>80</td>
<td>10 days</td>
</tr>
<tr>
<td>Elevated slabs or beams under 10 feet span</td>
<td>70</td>
<td>4 days</td>
</tr>
<tr>
<td>Post-tensioned systems</td>
<td>As soon as post-tensioning operations have been completed and approved</td>
<td></td>
</tr>
<tr>
<td>Arches</td>
<td>90</td>
<td>14 days</td>
</tr>
</tbody>
</table>

B. Remove forms without injuring concrete surfaces, overstressing concrete members, or distorting formwork. Do not pry against concrete.

C. Remove forms only if shores have been arranged to permit removal of forms without loosening or disturbing shores.

D. Post-Tensioned Construction: Post-tensioned system shall be stressed and approved by the Resident Engineer. Do not strip formwork supporting cantilever slabs or edge beams until backshores and/or reshores have been placed.

E. Cut nails off flush. Leave surfaces clean and unblemished.

### 3.04 SHORING, RESHORING, AND BACKSHORING

A. Provide shoring in conformance with the approved Shop Drawings.

B. In multistory construction, extend shoring, backshoring or reshoring over a sufficient number of stories to distribute loads in such a manner that no floor or member will be excessively loaded or will induce tensile stress in concrete members without sufficient steel reinforcement.
C. Keep reshores or backshores in place after placing upper tier for a minimum of 15 days or longer, as required, until concrete has attained its required 28-day strength and heavy loads due to construction operations have been removed.

D. Plan sequence of removal of shores and installation of backshores and reshores to avoid damage to concrete. Locate and provide adequate backshoring and reshoring to support construction without excessive stress or deflection.

E. Prevent construction loads on new construction during reshoring/backshoring.

3.05 CLEANING AND RE-USING FORMS

A. Clean and repair surfaces of forms to be reused.

B. Apply form release agent as specified for new formwork.

C. Patch holes and defects in forms with materials and methods that will not be reflected in the concrete.

D. Do not reuse forms with raised grain, torn surfaces, worn edges, patches, dents, or other defects that will impair the texture of the concrete surface.

3.06 FIELD QUALITY CONTROL

A. Before placing concrete, verify the following:
   1. Lines and levels of erected formwork are correct.
   2. Formed and embedded items are located correctly and secured against movement.
   3. Embedded piping and conduit are free from obstructions.
   4. Loose tie-wire and other debris have been removed from the forms.
   5. Surfaces of formwork and embedded items are free of mortar, grout, and other foreign matter.

B. While placing concrete, verify the following:
   1. Formwork geometry is maintained within specified tolerances.
   2. Cement paste is not lost through joints.

C. Monitor movement during concrete placement. Adjust formwork as necessary to maintain tolerances.
SECTION 03 15 00
CONCRETE ACCESSORIES

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for furnishing and installing joint fillers and sealing compounds for joints in concrete.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Concrete Institute (ACI)
      a. ACI 504R Guide to Joint Sealants for Concrete Structures
      a. ASTM D994 Preformed Expansion Joint Filler for Concrete (Bituminous Type)
      b. ASTM D1751 Preformed Expansion Joint Filler for Concrete Paving and Structural Construction (Nonextruding and Resilient Bituminous Types)
      c. ASTM D2628 Preformed Polychloroprene Elastomeric Joint Seals for Concrete Pavements
      d. ASTM D6690 Standard Specification for Joint and Crack Sealants, Hot Applied, for Concrete and Asphalt Pavements
      e. ASTM D7174 Standard Specification for Preformed Closed-Cell Polyolefin Expansion Joint Fillers for Concrete Paving and Structural Construction

1.03 SUBMITTALS
A. Shop Drawings: Include single-line diagram showing location and dimension of all joints to be filled and sealed.

B. Transmit: Product data, safety data, and installation instruction from product manufacturer.

C. Transmit: Samples: 12-inch long sample of joint filler and 1 pint or quart can of sealing compound to be submitted if requested by the Resident Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Premolded Joint Filler shall conform to ASTM D994 or ASTM D1751. For structural joints and joints subject to expansion, provide joint filler conforming to ASTM D7174.
B. Joint Seal: Conform to ASTM D2628, for sealing of joints in slabs and at junctions of slabs and vertical surfaces. Use color selected by the Resident Engineer from the manufacturer's standards.

C. Hot Poured Joint Sealant shall meet the requirement of ASTM D6690.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that concrete conditions comply with the requirements of the manufacturer’s written directions before installation.

B. Verify that weather conditions comply with the requirements of the manufacturer’s written directions before installation.

3.02 PREPARATION

A. Prepare the surface in conformance with manufacturer’s written instruction.

3.03 INSTALLATION

A. General: Install and protect joint sealant in conformance with manufacturer’s written instructions.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing waterstops in concrete.

1.02 REFERENCES
A. This Section incorporates by reference the latest revision of following documents:
   1. United States Army Corps of Engineers (COE)
      a. CRD-C-513 Rubber Waterstop
      b. CRD-C-572 Polyvinylchloride Waterstop

1.03 SUBMITTALS
A. Shop Drawings: Submit single-line diagram showing locations of all joints to receive waterstops, indicate type and size.
   1. Include locations for shop fabricated and field fabricated splices to be used in the Work.
B. Detail Drawings:
   1. Show location of waterstops.
   2. Show details of supports.
C. Transmit: Product Data:
   1. Manufacturers' product data showing conformance with this Section.
   2. Manufacturer’s written instructions for storage, handling, and installation.
   3. Material Safety Data Sheets if available.
D. Transmit: Samples: Submit the following:
   1. 12-inch long sample of each waterstop.

1.04 DELIVERY, STORAGE, AND HANDLING
A. Deliver, store, and handle waterstops in conformance with manufacturers’ written instructions.
PART 2 - PRODUCTS

2.01 MANUFACTURED PRODUCTS

A. PVC waterstops for construction and expansion joints meeting the requirements of US Corps of Engineers CRD-C-572.
   1. The PVC waterstop shall be extruded from an elastomeric plastic material of which the basic resin is prime virgin polyvinyl chloride.
   2. The PVC compound shall not contain any scrapped or reclaimed material or pigment.

B. Expansive waterstop comprised of hydrophilic, modified rubber meeting the requirements of US Corps of Engineers CRD-C-513.
   1. The waterstop shall be a combination of chloroprene rubber and chloroprene rubber modified to impart hydrophilic properties.
   2. The waterstop shall have a delay coating to inhibit initial expansion due to moisture present in fresh concrete.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Provide waterstops types and extents in locations as indicated on Contract Drawings.

B. Install waterstops in conformance with the manufacturer’s written instructions.
   1. Install waterstops accurately in place and secure rigidly against movement by methods adequate to assure proper support and embedment during the placement of concrete.
   2. Install waterstops in the longest practicable length, with joints spliced to form a continuous watertight seal for the full length of the joint.
   3. Carefully place and consolidate concrete to ensure a complete filling and bond between the concrete and waterstop. Cement-sand grout slurry may be used where necessary to assure contact and bond of waterstop and concrete without voids.
   4. PVC waterstops:
      a. Field butt splices shall be heat fused welded using a Teflon covered thermostatically controlled waterstop splicing iron at approximately 380 degrees F. Follow manufacturer’s recommendations.
      b. Lapping of waterstop and use of adhesives, or solvents shall not be allowed.
      c. Center waterstop in joint and secure waterstop in correct position using grommets, pre-punched holes, or hog rings spaced at 12” on centers along the length of the waterstop and wire tie to adjacent reinforcing steel.
   5. Expansive waterstops:
a. Cut coil ends square (or at proper angle for mitered corners) with shears or sharp blade to fit splices together without overlaps.

b. Splices and exposed end cells shall be sealed using manufacturer's approved adhesive.

C. Repair or replace damaged, defective or misaligned waterstop material in conformance with the manufacturer's instructions.

3.02 FIELD QUALITY CONTROL

A. Waterstop installation will be subject to inspection and acceptance by the Resident Engineer. Allow access for inspections.

END OF SECTION
SECTION 03 15 18
AERIAL GUIDEWAY EXPANSION JOINTS

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for furnishing and installing aerial guideway expansion joints at the locations shown in the Contract Drawings.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society for Testing and Materials International (ASTM)
      a. ASTM A588/A588M Standard Specification for High-Strength Low-Alloy Structural Steel, Up to 50 ksi Minimum Yield Point, with Atmospheric Corrosion Resistance
      b. ASTM D395 Standard Test Methods for Rubber Property – Compression Set
      c. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers – Tension
      e. ASTM D573 Standard Test Method for Rubber – Deterioration in an Air Oven
      f. ASTM D1149 Standard Test Methods for Rubber Deterioration – Cracking in an Ozone Controlled Environment
      g. ASTM D2240 Standard Test Method for Rubber Property – Durometer Hardness
      h. ASTM D3542 Standard Specification for Preformed Polychloroprene Elastomeric Joint Seals for Bridges

1.03 SUBMITTALS
A. Transmit: Product Data: Submit Certificates of Compliance for the expansion joints, confirming that the materials, fabrication, testing, and installation of the expansion joints are in conformance with these Specifications.
B. Transmit: Expansion joint system’s plan, elevation, section, location (bent number), nominal joint size or model number, and all dimensions for each expansion joint provided.
C. Shop drawings. Shop drawings shall explicitly set forth the proposed means by which the strip seal expansion joint shall be aligned and set to grade.
D. Transmit: Manufacturer’s written installation procedure and repair procedures if leakage testing fails or damage is found.
1.04 QUALITY ASSURANCE

A. The aerial guideway expansion joints shall be manufactured by a firm specializing in the design and fabrication of expansion joints for bridge or similar structures.

B. The manufacturer shall have a minimum of 5 years of experience specializing in expansion joints systems for similar applications.

C. The manufacturer of the expansion joints shall provide a technical qualified representative who will train the installer on the proper techniques for installing the seal.

PART 2 - PRODUCTS

2.01 MATERIALS

A. All materials shall be new and unused, with no reclaimed material incorporated in the finished expansion joints.

B. Expansion joints shall all be from the same manufacturer and shall be one of the following or approved equal:

1. Preformed, precompressed, self-expanding foam joint with silicone coating, epoxy bonded to sides of concrete surfaces, manufactured by EMSEAL for BEJS joint system (EMSEAL BEJS), or approved equal.

2. Preformed neoprene seal epoxy bonded to sides of concrete surfaces (neoprene seal). The manufacturer and system shall be one of the following or approved equal:
   a. D.S. Brown JP Series
   b. Watson Bowman Jeene FW Series Structural Sealing System

3. Strip seal expansion joints shall be preformed neoprene seals with embedded steel retainer rails, and shall be from the same manufacturer. The manufacturer shall be one of the following or approved equal:
   b. Watson Bowman Acme Wabo Strip Seal.

C. BEJS joint System by EMSEAL:

1. Provide materials meeting all requirements of EMSEAL for BEJS system or approved equal.

D. Neoprene:

1. The seal shall be preformed and manufactured from vulcanized elastomeric compound using polymerized chloroprene (neoprene) as the only base polymer.

2. The seal shall be prefabricated in the shop to fit the final dimensions of the joint as it occurs on the guideway. No field splices are allowed.

3. The seal material shall be from an extruded neoprene compound conforming to the physical properties shown in the table below, in accordance with ASTM D3542.
<table>
<thead>
<tr>
<th>Property</th>
<th>Requirements</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength</td>
<td>2000 PSI, min.</td>
<td>ASTM D412</td>
</tr>
<tr>
<td>Before aging:</td>
<td>20% Loss, max.</td>
<td>ASTM D573</td>
</tr>
<tr>
<td>After oven aging 70 hours @ 212 degrees F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elongation at Break</td>
<td>250%, min.</td>
<td>ASTM D412</td>
</tr>
<tr>
<td>Before aging:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After oven aging 70 hours @ 212 degrees F</td>
<td>20% Loss, max.</td>
<td>ASTM D573</td>
</tr>
<tr>
<td>Hardness, Type A Durometer</td>
<td>65±5 points</td>
<td>ASTM D2240</td>
</tr>
<tr>
<td>Before aging:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After oven aging 70 hours @ 212 degrees F</td>
<td>0 to +10 points</td>
<td>ASTM D573</td>
</tr>
<tr>
<td></td>
<td>After 7 days @ +14 degrees F</td>
<td>0 to +15 points</td>
</tr>
<tr>
<td>Ozone Resistance, under 20 percent strain:</td>
<td>No cracks</td>
<td>ASTM D1149</td>
</tr>
<tr>
<td>Weight change in oil after 70 hours at 104 degrees F in ASTM Oil No. 3, weight change:</td>
<td>45%, max.</td>
<td>ASTM D471</td>
</tr>
<tr>
<td>Compression Set, 70 hours @ 212 degrees F</td>
<td>40% max</td>
<td>ASTM D395</td>
</tr>
</tbody>
</table>

E. Epoxy adhesive: 2 part epoxy adhesive meeting the seal manufacture’s written requirements.

F. Steel retainer rails shall be ASTM A588/A588M. Retainer rails shall be one piece construction. All embedded metal items shall be galvanized according to shop applied coatings for metal requirements as stated elsewhere in the Contract Documents. Additionally, all embedded metal items’ exposed surfaces shall be coated with high performance coating, HPC-3, color Washington Gray as stated elsewhere in the Contract Documents.

2.02 FABRICATION

A. The seals shall be completely shop fabricated.

B. The size, shape, and dimensional tolerances of the seals shall be as shown on the Contract Drawings.

C. Two joint side surfaces shall be constructed straight and parallel to each other to the proper width and depth indicated on the Contract Drawings to prevent any wedging from expansion and contraction.

D. The seal shall be one continuous piece for the full length. Splices, stretched or glued joints shall not be allowed.

E. Shipping containers shall be clearly marked with the name of the manufacturer, lot number, and the date of manufacture.

F. Welding shall be in accordance with AWS D1.5. Welding procedures shall be submitted with shop drawings.
PART 3 - EXECUTION

3.01 INSTALLATION

A. The expansion joint assemblies shall be installed in accordance with the information shown in the Contract Drawings, the Shop Drawings and the manufacturer's recommendations.

B. A polyurethane backer rod shall be placed in the seal cavity of the strip seal steel retainer rails by the Contractor prior to pouring concrete and shall stay in place until concrete poured.

C. Installed expansion joints shall be watertight. After the joint system is installed, the joint shall be flooded with water and inspected, from below the joint, for leakage. If leakage is observed, the joint system shall be repaired by the Contractor, as recommended by the manufacturer. Inspect again after repair is done to ensure the expansion joint is watertight.

D. Installed expansion joints shall be free of damage. Repair any damage to expansion joints as a result of construction activities in accordance with manufacturer's written instructions. Inspect the repair to ensure the expansion joint is free of damage. Replace the joint system if damaged piece cannot be fixed.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for anchoring structural steel and metal fabrications to concrete and concrete masonry.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Iron and Steel Institute (AISI)
   a. AISI 304/316

   a. ASTM A108 Standard Specification for Steel Bars, Carbon, Cold-Finished, Standard Quality
   b. ASTM A1064 Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
   c. ASTM A563 Standard Specification for Carbons and Alloy Steel Nuts
   d. ASTM A706 Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
   e. ASTM A436 Standard Specification for Austenitic Gray Iron Castings
   f. ASTM F1554 Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength
   g. ASTM F436 Standard Specification for Hardened Steel Washers

   a. ANSI/AWS D1.1 Structural Welding Code – Steel
   b. ANSI/AWS D1.4 Structural Welding Code – Reinforcing Steel

1.03 SUBMITTALS

A. Transmit: Cast-In Concrete Anchors
   1. Mill certificates demonstrating conformance.

B. Transmit: Post-Installed Concrete Anchors:
   1. Manufacturer’s Product Data demonstrating conformance.
   2. Manufacturer’s written instructions for storage, handling, and installation.
C. Transmit: Welder Certification  
D. Transmit: Weld Procedure Specification  
E. Transmit: Source Quality Control inspection and test reports  
F. Transmit: Field Quality Control inspection and test reports

1.04 QUALITY ASSURANCE  
A. Welder Certification: Current Washington Association of Building Officials certification for each process, method, position, and size of weld executed.  
C. Post Installed anchors  
1. An on-site Quality Control Program shall be provided for all post-installed adhesive anchors in accordance with ICC-ES AC308 Articles 14.3 and 14.4  
2. Post-installed anchors shall be installed by an installer with a minimum of five years' experience performing similar installations.  
3. Installer Training: Conduct thorough training with the manufacturer or the manufacturer’s representative for the installer on the Project. Training shall consist of a review of the complete installation process for drilled-in anchors including, but not limited to, the following:  
   a. hole drilling procedure  
   b. hole preparation and cleaning technique  
   c. adhesive injection technique and dispenser training/maintenance  
   d. anchor element type, material, diameter, and length  
   e. proof loading/torquing

1.05 DELIVERY, STORAGE, AND HANDLING  
A. Deliver cast-in concrete anchor materials to the fabricator tied and identified with plastic tags indicating the mill, melt or heat number, and the grade and size of bar.  
B. Store and handle concrete anchors in conformance with manufacturer’s written instructions.

PART 2 - PRODUCTS

2.01 CAST-IN CONCRETE ANCHORS  
A. Reinforcing Bars: ASTM A615/A706  
B. Anchor Rods  
   1. ASTM F1554 Grade 36 with ASTM A563A hex nuts  
   2. ASTM F1554 Grade 105 with ASTM A563DH heavy hex nuts
3. Washers: ASTM F436

4. Finish: Section 05 05 13, Shop-Applied Coatings for Metal

C. Welded Headed Studs: ASTM A108, grades 1015 through 1020, headed stud type, cold finished carbon steel, AWS D1.1, Type B; with fluxed end conforming to ANSI/AWS D1.1.

D. Deformed Bar Anchors: ASTM A1064 with fluxed end conforming to ANSI/AWS D1.1.

2.02 POST-INSTALLED CONCRETE ANCHORS

A. Expansion Anchors

1. Hilti Kwik Bolt TZ, Powers Power-Stud+SD2, Simpson Strong-Bolt 2, or approved equal.

B. Adhesive Anchors

1. Adhesive: Hilti HIT–RE 500-SD, Powers PE 1000+, Simpson Set-XP, or approved equal.

C. Undercut Anchors


D. Screw Anchors

1. Hilti Kwik HUS-HR, Powers Wedge-Bolt+, Simpson Titen HD, or approved equal. Permanent screw anchors may only be used for interior, non-corrosive applications.

E. Substitute Products: Substitute post-installed concrete anchor products, if submitted, shall have current International Code Council approval for use in cracked concrete.

2.03 WELDING ELECTRODE

A. Match filler metal requirements in conformance with ANSI/AWS D1.4

2.04 FABRICATION

A. Reinforcing Bars Noted A706

1. Fabrication: Section 03 20 00, Concrete Reinforcing

2. Welding: ANSI/AWS D1.4

B. Welded Headed Studs: Weld to structural steel and metal fabrications in conformance with ANSI/AWS D1.1 and manufacturer's written instructions.

C. Deformed Bar Anchors: Weld to structural steel and metal fabrications in conformance with ANSI/AWS D1.1 and manufacturer's written instructions.

2.05 SOURCE QUALITY CONTROL

A. Visually inspect all shop welds.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Cast-In Concrete Anchors

1. Anchor Rods: Install anchors as indicated on Contract Drawings. Secure to formwork or reinforcement to prevent movement during concrete placement. Protect threads until structural steel or metal fabrication is installed.

2. Other Cast-In Concrete Anchors: Install anchors with fabricated assembly in conformance with Section 03 11 00, Concrete Forming.

B. Post-Installed Concrete Anchors

1. Post-installed anchors may only be installed in sound concrete. Surfaces showing obvious distress by way of porosity, disintegration, carbonation, and cracks over 0.02-inch in width and 12-inches or longer and within the distance of the embedment length shall be reported to the Resident Engineer.

2. Preparation for drilling

   a. Existing reinforcement shall be detected as indicated on the Contract Drawings to establish the reinforcement pattern before drilling.

   b. No cutting of reinforcement will be permitted without prior written approval from the Engineer. Multi-cutting of the same bar is considered as one cut.

   c. Reinforcement will be considered to be cut if:

      1) For No. 4 through No. 7: Cuts, nicks, or drill into bar body are greater than 1/16-inch

      2) For No. 8 and Larger: Cuts, nicks, or drill into bar body are greater than 1/8-inch

   d. When installing anchors through cut reinforcement, the anchoring mechanism shall be located at least two anchor diameters beyond the cut reinforcement.

3. Post-installed anchors shall be installed in accordance with the ICC-ES reports and manufacturer’s installation instructions. Where installation criteria differ, the order of precedence from highest to lowest is: 1) this Specification; 2) the ICC-ES reports; 3) the manufacturer’s installation instructions.

4. Holes for post-installed anchors shall be drilled with carbide-tipped bits using rotary hammer drills meeting the requirements of ANSI B212.15 unless ICC-ES AC193 or ICC-ES AC308 testing demonstrates that using percussive drilling or another type(s) of bit, including core drills, is acceptable. Drilled holes shall be cleaned of chips, dust, loose material, and water prior to anchor installation. The hole diameters and depths shall be as recommended in the manufacturer’s instructions. The hole diameter shall be checked every ten holes for conformance to the hole tolerances specified in ICC-ES AC308 for adhesive anchors, ICC-ES AC193 or ACI 335.2 for mechanical anchors. Verify depth of the concrete member before drilling holes. The embedment depth of the post-installed anchor shall not exceed the greater of 2/3 of the concrete member thickness or the...
concrete member thickness minus 4-inches. Contact the Engineer if these requirements cannot be met based on the actual member thickness.

5. Anchors shall be installed perpendicular to the concrete surface within a plus or minus 5-degree tolerance. Post-installation verification of this criterion may be satisfied by visual inspection to verify proper seating of the nut and washer.

6. In areas where concrete has been removed, the minimum anchor embedment shall be measured from the surface of sound concrete.

7. Unless otherwise noted on the Contract Drawings, the spacing requirements indicated in the applicable ICC ES report shall be used.

8. Bending and welding of post-installed anchors is not permitted.

9. The nut thread engagement for the anchors (studs) shall be such that the bolt threads project past the outside face of the nut when completely installed.

10. The length identification code on the head of the anchor shall not be damaged during installation. Anchor projection may be cut-off subject to the approval of the Engineer and documentation of the location, embedment, and length code.

11. Unused anchors shall be driven in and cut-off flush. Cut-off anchors shall be considered an abandoned ungrouted hole for future anchor spacing requirements.

12. Care shall be exercised to avoid bending anchors to match base plate holes, or loosening of anchors by prying sideways after tightening. Care shall also be exercised to ensure that the cone nut of an undercut anchors does not become loose from the stud during the setting or tensioning operation.

13. Non-grouted base plates may have a maximum 1/8-inch gap as evidenced under exterior edges around the plate provided that 1) the plate exhibits bearing contact within its interior against the concrete surface; and 2) the uneven bearing does not prevent application of the prescribed torque. If an unacceptable bearing contact condition exists, one of the following procedures shall apply:

   a. The concrete surface shall be reworked to obtain a proper fit.

   b. For gaps of up to 1-inch, the base plate may be grouted instead using the following technique:

      1) Insert post-installed anchors and set the base plate.

      2) Insert nuts to finger-tight condition.

      3) Install shims positioned no more than 1/2-inch away from the anchors to reduce gaps between base plate shims to 1/8-inch or less at anchor locations.

      4) Apply tightening torque. The bolt tightening shall not be performed when interior shims under the base plates have been placed away from anchors so that downward bending of the base plate would result upon tightening. Shims shall be moved as close as possible to the anchors before applying the installation torque.

      5) Fill the gap with non-shrink grout leaving the shims in place. For base plates on walls where grouting is not feasible, the gap may
be filled with shim plates. The shims may be stacked but no more than four shims shall be stacked.

14. Relocating Holes Within Base Plates: The base plate with bolts may be relocated no more than 1-inch in any direction with respect to the attachment principal axis unless otherwise noted on the Contract Drawings.

15. Do not use adhesive anchors for conditions that place constant tensile loads on the anchor.

3.02 FIELD QUALITY CONTROL

A. Post-Installed Concrete Anchors

1. Full-time special inspection is required for all adhesive anchor systems together with proof load testing. Proof load testing alone is not recognized as meeting special inspection requirements.

2. Testing Method: Post-installed anchors shall be tested by the direct tension method as follows:

a. Direct Tension Method: A tensile load as defined herein below is applied. If the tension load is applied by jacking against the concrete, the jacking pressure shall be distributed outside of an area having its center at the post-installed anchor and its diameter, or least dimension, equal to the required anchor spacing as given in the ICC ES report. Post-installed anchors tested by this method shall be retightened by applying the installation torques.

b. Testing shall be in accordance with {ICC-ES AC308 Figure 5-1} or {ACI 355.2 and ASTM E488}.

3. Test (Proof) Load: Tension test (proof) load shall be as indicated on the approved shop drawings.

4. For post-installed adhesive anchors, the test shall be equal to the lesser of:

a. A tensile load equal to 80-percent of the specified nominal yield strength of the anchor bolt material times the tensile area of the bolt; or

b. A tensile load equal to twice the design load and at least 50 percent of the expected ultimate load based on the adhesive bond strength shown in the ICC-ES report, whichever is greater.

5. For post-installed mechanical anchors, the test load shall be a tensile load equal to 80-percent of the specified nominal yield strength of the anchor bolt material times the tensile area of the bolt.

6. Test Frequency: Unless otherwise specified, the following test frequencies shall apply:

a. Post-Installed Mechanical Anchors: All anchors shall be tension-tested.

b. Post-Installed Adhesive Anchors: All anchors shall be tension-tested.

7. Acceptance Criteria: A post-installed anchor is acceptable if the test load specified herein is attained without:

a. Slippage of more than:
1) 1/16-inch for adhesive anchors

2) 2.5-percent of the embedded length, rounded to the nearest 1/16-inch for mechanical anchors

b. Bolt failure
c. A sign of damage in the surrounding concrete

8. Installation Inspection Record
   a. Test Inspection Record: The test inspection record shall include, but not be limited to, the following information:
      1) Product description, including product name
      2) Adhesive expiration date
      3) Anchor or rebar diameter and steel grade
      4) General location of anchor and group represented
      5) Method of test or verification
      6) Test results, accepted or rejected
      7) Inspector’s name
      8) Date of test
      9) Identification number of testing tool
   b. Failed Anchor Documentation: Documentation for anchors is required for an anchor that does not pass the test acceptance criteria specified herein. Failed anchor documentation shall be submitted to the Engineer. The documentation shall include, but not be limited to, the following:
      1) Exact location of failed anchor
      2) Reason for failure
      3) Repair steps taken
      4) Inspector’s name
      5) Date of test

3.03 REPAIR AND RESTORATION OF DEFECTIVE WORK

1. Remove and replace misplaced or malfunctioning anchors. Fill empty anchor holes and patch failed anchor locations with high-strength non-shrink, nonmetallic grout. Anchors that fail to meet proof load or installation torque requirements shall be regarded as malfunctioning.

2. Abandoned holes shall be grouted with non-shrink grout. When post-installed anchors fail to meet the acceptance criteria under inspection and testing, the following repairs may be undertaken:
   a. When failure is due to excessive anchorage pullout, contact the Engineer to evaluate the damage and approve a repair method. If approved, the anchor may be reset once prior to redrilling the hole and installing an
anchor of equal size. Use the minimum spacing embedment depth, and installation torque required for the original anchor.

b. When failure is due to breaking of the anchor, slippage or loosening, bending, improper installation or poor attachment, remove the defective anchor, redrill the hole, and install the same diameter anchor if the integrity of surrounding concrete has not been disturbed.

c. For cases where excessive slippage upon torquing is experienced, or usage of the same hole is not possible, fill the existing hole with non-shrink grout and relocate the anchor location.

d. When failure is due to breakout of concrete around the anchor, the Engineer will develop an appropriate repair. Contact the Engineer to evaluate the damage and repair method. Local spalling of the concrete around the anchor, up to a maximum depth of 1/4-inch, is not considered a concrete breakout failure.

e. Mislocated anchors may be cut flush with concrete surface, and need not be removed if they do not interfere with subsequent installations.

f. Mislocated anchors or anchors installed for temporary applications may be left in place. Those anchors that must be removed to accommodate other attachments, aesthetics, or safety of personnel may be removed completely or abandoned in place by cutting off beneath the surface after chipping the concrete 1-inch minimum and patching with epoxy grout. Mislocated anchors that will be covered by a base plate or an attachment may be cutoff flush with the concrete. In the event that an anchor must be removed from the hole and a new anchor installed, the removal and installation of the new anchor shall be in accordance with the manufacturer’s specifications. The abandoned hole or removed concrete shall be filled with non-shrink grout.

g. Removal of installed anchors for inspection or replacement may be performed by using a bolt extractor as manufactured by Drillco Devices, Ltd., or approved equal.

h. Retest all replaced anchors as specified herein.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for fabrication, welding, and placement of steel reinforcing for concrete, and concrete reinforcing accessories.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Concrete Institute (ACI)
   a. ACI 116R Cement and Concrete Terminology
   b. ACI 117 Standard Specifications for Tolerances for Concrete Construction and Materials
   c. ACI 315 Details and Detailing of Concrete Reinforcement
   d. ACI 318 Building Code Requirements for Reinforced Structural Concrete

   a. ANSI/AWS D1.4 Structural Welding Code – Reinforcing Steel

3. American Society for Testing and Materials International (ASTM)
   a. ASTM A82 Steel Wire, Plain, for Concrete Reinforcement
   b. ASTM A1064 Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
   c. ASTM A615 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
   d. ASTM A706 Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
   e. ASTM A970 Standard Specification for Headed Steel Bars for Concrete Reinforcement
   f. ASTM A1035 Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement
   g. ASTM A1064 Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

4. Concrete Reinforcing Steel Institute (CRSI)
   a. CRSI Manual of Standard Practice
   b. CRSI Publication, Placing Reinforcing Bars
1.03 DEFINITIONS
A. Placing Drawings: Working drawings showing the grade, quantity, size, length, and location of the reinforcing steel necessary for the fabrication and placement of the material, including bending schedules, bending details, and material lists (bills of material)
B. With the above exception, the words and terms used in this Section conform to the definitions given in ACI 116R.

1.04 SUBMITTALS
A. Shop Drawings
   1. Detail reinforcing steel in conformance with ACI 315.
   2. Furnish bar lists, bending diagrams and schedules. Include weights on bar lists.
   3. Indicate locations for placement of reinforcing and reinforcing support. Include number of pieces, size, and markings of reinforcing steel.
   4. Indicate locations of lap splices, welds, mechanical splices, and mechanical anchors.
   5. Indicate locations of anchors, hangers, inserts, bolts, conduits, sleeves, block outs, and other items to be cast in concrete for possible interference with reinforcing steel.
   6. Identify the specification and grade of the reinforcing steel to be placed at each location.
B. Transmit: Mill Certificates: For each lot or load of reinforcing steel delivered to the jobsite, submit mill certificates demonstrating conformance to the requirements of this Section.
C. Transmit: Evaluation Reports: Submit Evaluation Reports from the ICC Evaluation Service, Inc., demonstrating conformance to the requirements of this Section for:
   1. Mechanical splices
   2. Mechanical anchorages
D. Transmit: Manufactured Products: For each manufactured product submit:
   1. Manufacturer’s Product Data.
   2. Manufacturer’s written instructions for storage, handling, and installation.
E. Transmit: Welder Certifications: Submit current Washington Association of Building Officials reinforcing steel welding certifications for each welder, valid for each process, method, position, and bar size used.
F. Transmit: Welder Procedures Specification: Submit welding procedures specification for all reinforcing steel welds in conformance with ANSI/AWS D1.4
G. Transmit: Test Reports
   1. Reports for weld procedure qualification
   2. Test reports demonstrating acceptance of weld procedure specifications
3. Shop and field weld inspection reports

1.05 DELIVERY STORAGE AND HANDLING

A. Deliver reinforcing steel to the fabricator in bundles, limited to one size and length of bar, securely tied and identified with plastic tags in an exposed position indicating the mill, the melt or heat number, and the grade and size of bars.

B. Deliver reinforcing steel to the jobsite properly tagged and identified.
   1. Store, block up and protect in a manner that will prevent damage.
   2. Protect from moisture, dirt, grease, oil, and other foreign materials that might impair bond with concrete.
   3. Maintain identification of reinforcing steel after bundles are broken.

C. Store and handle manufactured items in conformance with manufacturer’s written instructions.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Deformed Bars
   1. Reinforcing Steel Bars: ASTM A615, Grade as indicated on the drawings.
   2. Weldable Reinforcing Steel Bars (including Cathodic Protection and Grounding reinforcement): ASTM A706, Grade 60, unless otherwise indicated. Grade 80 bars shall not be spliced or coupled, unless otherwise noted in plans.

B. Welded Wire Fabric
   1. Plain Wire: ASTM A185
   2. Deformed Wire: ASTM A497

C. Smooth Dowel Bars: ASTM A615 Grade 60

D. Wire and Plain Bars: ASTM A1064

E. Tie Wire: ASTM A82, No. 16 gauge or heavier, black or galvanized, soft or commercial grade steel tie wire.

F. Accessories:
   2. Provide metal chairs with Class 1 or Class 2 protection.
   3. Provide concrete blocks with compressive strength equal to or greater than the concrete being placed.

G. Mechanical Splices
   1. Capable of being installed in clear space indicated.
2. Mechanical Splices shall conform with Type 1 or 2 in accordance with ACI 318-08 Sections 12.14.3.2 and 21.1.6.

H. Mechanical Anchorages
1. Capable of being installed in clear space indicated.
2. Capable of developing at least 125 percent of the yield strength of anchored reinforcing bar.

I. Welding Electrodes
1. Match filler metal requirements in conformance with ANSI/AWS D1.4/D1.4M

2.02 FABRICATION

A. Conform approved placing drawings.

B. Cutting and Bending
1. Perform cutting and bending at a central location, equipped and suitable for the purpose.
2. Accurately cut and cold bend bars as indicated on the approved placing drawings. Do not heat bars for bending or straightening. Do not bend, rebend or straighten bars in a manner that will injure the material.
3. Do not use straightened bars.
4. Label all bars in conformance with approved placing drawings. Secure like pieces in bundles when appropriate.

C. Welding: ANSI/ AWS D1.4

2.03 SOURCE QUALITY CONTROL

A. Tolerances

B. Identification
1. Bundle and tag reinforcing steel with grades and sizes, heat numbers, and suitable identification marks for checking, sorting, and placing.
2. Mark tags with sizes and numbers corresponding to approved placing drawings and schedules.
3. Use waterproof tags and markings that cannot be removed until steel reinforcement is placed in position.

C. Shop Welding Inspection:
1. Inspect all shop welds in conformance with ANSI/AWS D1.4.
PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to placing reinforcing:
   1. Verify that surfaces over or against which reinforcing is to be placed are clean and in proper condition for placing reinforcement.
   2. Verify items to be embedded in concrete are secured in place.

3.02 PLACEMENT

A. General
   1. Install concrete reinforcing in conformance with approved placing drawings.
   2. Install reinforcement accurately and secure against movement from concrete placement.
   3. Do not cut, bend, or straighten bars in the field unless directed by Resident Engineer.

B. Reinforcing Supports: Support bars on metal chairs, concrete blocks, spacers, and/or hangers, accurately placed and securely fastened to steel reinforcement in place. Support legs of accessories in forms without embedding in the form surface. Support epoxy-coated reinforcing on epoxy coated or other dielectric-polymer-coated wire bar supports or plastic bar supports.

C. Placing and Tying: Install reinforcing steel in place securely to prevent displacement. Bend ends of wire ties away from forms. Do not secure bars to the sides or bottom of the forms using tie wire. Tie epoxy-coated reinforcing with epoxy-coated tie wire. Tack welding is not permitted on reinforcing steel.

D. Lap Splices: Stagger splices of alternate bars a minimum clear offset of 4 feet between splices, unless noted otherwise on Contract Drawings, or as indicated on the approved placing drawings.

E. Mechanical Splices: Install in conformance with the manufacturer's written instructions. Where mechanical splices are connected to reinforcement on only one end and embedded in concrete, provide a metal cap on the open end to protect the interior of the splice and prevent intrusion of concrete.

F. Mechanical Anchorages: Install in conformance with the manufacturer's written instructions.

G. Dowels: Provide additional bars for proper support of dowels where required. Furnish and use templates for placement of column dowels. Provide additional bars for proper support and anchorage where required. Do not bend dowels after embedment.


I. Concrete Cover: Provide concrete cover over steel reinforcement as shown on Contract Drawings.
J. Protection of Waterproofing Membrane: Where reinforcement is to be installed over a waterproofing membrane, protect the membrane during installation of the reinforcement to avoid punctures, tears, and abrasion. Notify the Contractor’s Quality Assurance Manager and the Resident Engineer immediately if the membrane is damaged.

3.03 CLEANING
A. Clean reinforcement free of foreign materials that might impair bond with concrete.

3.04 REPAIR
A. Repair damaged epoxy coating with epoxy repair coating.

3.05 FIELD QUALITY CONTROL
1. Adjustment: Bars may be moved as necessary to avoid interference with other reinforcing steel or embedded items. Do not increase the maximum spacing or reduce the total number of bars. Replace and secure all bars moved to permit access for cleanup operations before the start of concrete placement.

B. Perform the following tests with the Contractor’s Quality Assurance Manager and the Resident Engineer present during reinforcing placement:
1. Mechanical Splices
   a. Provide continuous inspection of 100 percent of installed splices.
   b. Remove and replace incorrectly installed splices
2. Mechanical Anchorages and Anchorages
   a. Provide continuous inspection of 100 percent of installed anchorages.
   b. Remove and replace incorrectly installed anchorages.
3. Field Welding
   a. Visually inspect all field welds in conformance with ANSI/AWS D1.4.

C. Perform the following inspections with the Contractor’s Quality Assurance Manager and the Resident Engineer present prior to placing concrete:
1. Placement: Visually inspect reinforcing placement for conformance with the placing drawings. Verify the following:
   a. Bar grade
   b. Bar size, length, and bends
   c. Bar location, quantity, spacing, and cover
   d. Lap splice types, lengths, and locations
   e. Sufficient ties, supports, and side form spacers
   f. Bars are free from foreign materials that might impair bond with concrete.
2. Waterproofing Membrane: Verify integrity of waterproofing membrane.
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for conveying, placing, curing, protecting, and testing cast-in-place concrete.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Concrete Institute (ACI)
   a. ACI 116R Cement And Concrete Terminology
   b. ACI 301 Specifications For Structural Concrete
   c. ACI 304R Guide For Measuring, Mixing, Transporting, And Placing Concrete
   d. ACI 304.2R Placing Concrete by Pumping Methods
   e. ACI 305R Hot Weather Concreting
   f. ACI 306.1 Standard Specifications For Cold Weather Concreting
   g. ACI 309R Guide For Consolidation Of Concrete
   h. ACI 503.4 Standard Specification For Repairing Concrete With Epoxy Mortars

   a. ASTM C31 Standard Practice For Making And Curing Concrete Test Specimens In The Field
   b. ASTM C33 Standard Specification For Concrete Aggregates
   c. ASTM C39 Standard Test Method For Compressive Strength Of Cylindrical Concrete Specimens
   d. ASTM C42 Standard Test Method For Obtaining And Testing Drilled Cores And Sawed Beams Of Concrete
   e. ASTM C94 Standard Specification For Ready-Mixed Concrete
   f. ASTM C143 Standard Test Method For Slump Of Hydraulic Cement Concrete
   g. ASTM C150 Standard Specification For Portland Cement
   h. ASTM C171 Standard Specification For Sheet Materials For Curing Concrete
i. ASTM C172 Standard Practice For Sampling Freshly Mixed Concrete
k. ASTM C231 Standard Test Method For Air Content Of Freshly Mixed Concrete By The Pressure Method
l. ASTM C309 Standard Specification For Liquid Membrane Forming Compounds For Curing Concrete
m. ASTM C470 Standard Specification for Molds for Forming Concrete Test Cylinders Vertically
n. ASTM C881 Standard Specification For Epoxy Resin Base Bonding Systems For Concrete
o. ASTM C928 Standard Specification For Packaged, Dry, Rapid-Hardening Cementitious Materials For Concrete Repairs
p. ASTM C1059 Standard Specification For Latex Agents For Bonding Fresh To Hardened Concrete
q. ASTM C1064 Standard Test Method for Temperature of Freshly Mixed Hydraulic Cement Concrete
r. ASTM E329 Standard Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

3. American Association of State Highway and Traffic Officials (AASHTO)
a. AASHTO M182 Specification For Burlap Cloth Made From Jute or Kenaf

4. Washington State Department of Transportation (WSDOT)
a. Standard Specifications for Road, Bridge, and Municipal Construction

5. Other Standards
   a. City of Seattle: Standard Specifications for Road, Bridge and Municipal Construction

1.03 DEFINITIONS
   A. Mass Concrete: Consider structural concrete to be mass concrete when the minimum cross sectional dimension is equal to or greater than 4 feet, or when Type III cement, accelerating admixtures, or cementitious materials in excess of 660 lb/yd3 of concrete are used. Concrete in shafts meeting drilled shaft concrete mix requirements, a maximum temperature at placement of 70 degrees Fahrenheit, and a minimum amount of 25% fly ash are excluded from mass concrete requirements.

1.04 SUBMITTALS
   A. Transmit: For each manufactured product submit:
      1. Manufacturer's Product Data showing conformance with the requirements of this Section.
3. Manufacturer’s written instructions for storage, handling, and installation

B. Transmit: Qualifications: Independent Testing Laboratory

C. Construction Work Plan including provisions for hot weather concreting and curing, cold weather concreting and curing, and wet weather concreting and curing.

D. Thermal Control Plan

E. Quality Program Plan

F. Transmit: Placement Records: Report the location in the finished work of each concrete class, and the start and completion times of each batch of concrete placed.

G. Transmit: Field Quality Control inspection and test reports and documents
   1. Concrete slump, air content, and temperature results
   2. Concrete compressive strength test results
   3. Concrete truck batch tickets in conformance with ASTM C94. Include any modifications to water or admixture volumes from the original mix design.
   4. Thermal control records

1.05 QUALITY ASSURANCE

A. Construction Work Plan: Include descriptions of methods, materials, labor, and equipment used in:
   1. Conveying, placing, curing, and protecting cast-in-place concrete
   2. Sampling and testing cast-in-place concrete.
   3. Hot weather concreting, cold weather concreting, and wet weather concreting

B. Thermal Control Plan: Develop plan with concrete supplier describing means and methods of monitoring internal and differential temperature of mass concrete, and mitigating damage to concrete due to heat of hydration of the cement and attendant volume changes. Include the following:
   1. Concrete mix designs
   2. Duration and methods of curing.
   4. Methods of applying immediate corrective action should the temperature limits be exceeded.
   5. Temperature monitoring system. Include system description, sensor types and locations, and manufacturer’s product information, Furnish readout device with chart recorder. Furnish sample thermal control report.
   6. Method of sensor installation, connection to readout device, protection during placement and curing, reading, and decommissioning.

C. Independent Testing Laboratory technicians shall have ACI Grade I Concrete Field Testing Technician Certification.
1.06 DELIVERY, STORAGE, AND HANDLING

A. Ready Mix Concrete: Section 03 05 15, Portland Cement Concrete.

B. Store and handle manufactured products in conformance with manufacturer's written instructions.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Portland Cement For Site-Mixed Repair Materials
   1. ASTM C150, type and brand to match cement used in concrete to be repaired.
   2. Provide white portland cement where required to match surrounding concrete.

B. Fine Aggregate for Site-Mixed Repair Materials
   1. For Bonding Grout: ASTM C33 washed clean sand passing a Number 30 sieve.
   2. For Patching Mortar: ASTM C33 washed clean, graded fine aggregate of suitable size for areas to be repaired. Aggregate up to Size Number 8 may be used for repair of larger defects.

2.02 MANUFACTURED PRODUCTS

A. Patching Mortar: ACI 503.4 for Epoxy Mortar.

B. Epoxy Adhesive: ASTM C881
   1. Type II for non-load-bearing concrete, Type V for load-bearing concrete
   2. Select grade and class by project conditions and requirements

C. Damp Curing Materials
   1. Waterproof Sheet Materials: ASTM C171 waterproof paper with white paper face, polyethylene film pigmented white or white burlap-polyethylene sheeting
   2. Burlap: AASHTO M182, class or weight suitable for the use and location

   1. Type 1 for concrete not exposed to sunlight, Type 1-D with white fugitive dye for concrete exposed to sunlight
   2. Class A or B as appropriate for use and location

E. Patching Materials Other Than Portland Cement
   1. Portland cement mortar modified with a latex bonding agent conforming to ASTM C1059 Type II
   2. Epoxy mortars and epoxy compounds that are moisture-insensitive during application and after curing, that embody an epoxy binder conforming to ASTM C881, Type III. Select type, grade, and class appropriate for the application.
   3. Non-shrink grout: Section 03 62 00, Non-Shrink Grouting
4. Packaged, dry concrete repair materials conforming to ASTM C928

F. Evaporation Retarder
   1. Eucobar by Euclid Chemical
   2. Evapre by W. R. Meadows
   3. Aquafilm by Dayton Superior

G. Silane Sealer with 40% solids
   1. Baracade Silane 40 by Euclid Chemical
   2. MasterProtect H 440HZ by BASF

2.03 MIX DESIGNS
A. Mix Designs: Section 03 05 15, Portland Cement Concrete

PART 3 - EXECUTION
3.01 PREPARATION
A. Notification: Prior to each concrete placement:
   1. Notify the Resident Engineer at least 24 hours prior to actual placement, and not later than 3 pm on the day prior to placement.
   2. Notify the Resident Engineer at least 48 hours prior to actual placement when schedules require concrete placement at times other than normal working hours or for Mass Concrete pours.
   3. Notify the Resident Engineer of the location of the placement and the concrete mix to be placed.

B. Prior to placement, verify the following:
   1. Formwork installation conforms to Section 03 11 00, Concrete Forming.
   2. Reinforcing placement conforms to Section 03 20 00, Concrete Reinforcing.
   3. Embedded items are located correctly and secured to resist movement.
   4. For slabs on grade, also verify the subgrade is well drained; free of debris, free of frost and ice; and moist with no muddy spots, soft spots, or ruts.

C. Construction Joints
   1. Make construction joints straight and as inconspicuous as possible, and in vertical and horizontal alignment with the structure.
   2. Locate construction joints as indicated on the Contract Documents, and according to 03 11 00, Concrete Forming.
   3. Install waterstops in conformance with Section 03 15 13, Waterstops.
4. Before placing fresh concrete against cured concrete, the Contractor shall thoroughly clean the cured surface. Apply epoxy adhesive to hardened concrete in conformance with manufacturer’s written instructions.

D. Obtain acceptance of preparation from the Resident Engineer and special inspection firm prior to placement.

E. Waterproofing Membrane: Where concrete is to be placed over a waterproofing membrane, obtain acceptance of the membrane integrity from the Resident Engineer prior to concrete placement.

F. Weather Considerations

1. Wet Weather: Do not place concrete while rain, sleet, or snow is falling unless protection is provided. Do not allow rain to increase mixing water or damage unformed surfaces.

2. Hot Weather: Conform to ACI 305R

3. Cold Weather: Conform to ACI 306.1

3.02 MEASURING, BATCHING AND MIXING

A. Measure, batch and mix Portland Cement concrete in conformance with ASTM C94.

1. Use central-mixed concrete transported to the jobsite in truck mixers.

2. Use truck mixers equipped with:
   a. Automatic device for recording number of revolutions of drum prior to completion of mixing operation.
   b. Either accurately calibrated water tanks or water meters.

3.03 DELIVERY

A. Refer to 03 05 15 Portland Cement Concrete.

3.04 SLUMP ADJUSTMENT

A. Refer to 03 05 15 Portland Cement Concrete.

3.05 PLACEMENT

A. Conveying

1. General
   a. Convey concrete rapidly from mixer to the place of final deposit using methods that prevent segregation and loss of ingredients, and will ensure the required quality of concrete.
   b. Do not use aluminum pipes or chutes.
   c. Conform to ACI 304R

2. Pumping
   a. Conform to ACI 304.2R.
b. Use pumping equipment that permits placement rates that avoid cold joints and prevent segregation in discharge of pumped concrete.

c. Support pump hoses so that reinforcement is not moved from its original position.

B. Depositing

1. Place concrete continuously in one horizontal layer or in several horizontal layers with fresh concrete deposited over previous placements that are still plastic.

2. Do not place concrete that has surface-dried, partially hardened, or contains foreign material.

3. Do not drop concrete freely through reinforcing which may cause segregation.

4. Do not drop concrete freely more than 5 feet. When placing vertical sections of greater heights, use openings in the form, elephant trunks, tremies, or other approved devices to reduce the free drop.

5. Placement Using Tremie Methods: Place concrete in or under water in conformance to ACI 304R.

6. If truck is being sampled, no placement shall be made until tests demonstrate concrete conforms to temperature, air content, and slump requirements.

C. Consolidating

1. Consolidate concrete by mechanical vibration in conformance with ACI 309R.

2. Thoroughly work concrete around reinforcement and embedded items and into corners of forms to eliminate air and rock pockets. Insert and withdraw the vibrator vertically at uniform spacing over the entire area of the placement. Space the distance between insertions such that the influence zones of each insertion overlap. Do not drag vibrators to move concrete horizontally.

3. Use internal vibrators of the largest size and power that can properly be used in the Work. Maintain vibrators and provide sufficient back-up units on site.


3.06 CURING AND PROTECTION:

A. Curing Unformed Concrete Surfaces at Station Platforms

1. The concrete surfaces shall be cured in accordance with the WSDOT Standard Specifications Section 6-02.3(11)B, except as noted below:

   a. The wet curing requirement as described shall remain in place for at least 7 consecutive calendar days.

   b. Curing concrete by spraying curing compound only is not allowed for station platforms.

B. Curing Unformed Concrete Surfaces other than Station Platforms

1. Apply evaporation retardant, immediately after placing, in accordance with manufacturer’s instructions.

2. Apply curing compound in accordance with manufacturer’s instructions.
C. Curing Formed Concrete Surfaces
   1. Keep absorbent wood forms wet until they are removed.
   2. After formwork is removed, apply a curing compound.

D. Protection
   1. Immediately after placing, protect concrete from premature drying, excessively hot or cold temperatures, mechanical injury, and staining.
   2. Protect concrete during the curing period from mechanical and physical stresses that may be caused by heavy equipment movement, subjecting the concrete to load stress, load shock, or excessive vibration.
   3. Where concrete surfaces will receive architectural finishes, such as clear or penetrating pigmented sealer/densifier, resilient floor coverings or paint, ensure membrane-forming curing compound does not leave a coating or residue that will impair application or bond of sealers, adhesives, paints, and coatings with concrete.

E. Parking Garages
   1. Apply 40% solids silane sealer in accordance with manufacturer’s instructions.

3.07 THERMAL CONTROL
A. Limit concrete maximum internal temperature to 160 degrees F. Limit maximum differential temperature to 35 degrees F, between the middle of the placement and at a point 2 inches interior to the surface.

B. Demonstrate that concrete temperatures do not exceed the specified limits.
   1. Test concrete temperatures in conformance with ASTM C186
   2. Record internal and surface temperatures
      a. Hourly until internal concrete temperature has dropped to less than 90 percent of the maximum recorded.
      b. As necessary until trend indicates internal and surface concrete temperatures are converging.
   3. Provide chart recorder to document temperatures and submit records as part of Article 3.10.

3.08 FIELD QUALITY CONTROL
A. Independent Testing Laboratory: Use an Independent Testing Laboratory to perform the following:
   1. Record all concrete batched
   2. Record all concrete delivered to the project
   3. Collect and check concrete truck batch tickets
   4. Visually inspect concrete placement
5. Sample and test concrete
6. Obtain drilled cores of concrete, if required by the Resident Engineer
7. Install and read temperature measurement devices in mass concrete placements
8. Prepare reports on all inspection and test results

B. Provide additional labor, materials, or equipment required to assist the Independent Testing Laboratory in obtaining and handling samples at the site.

C. Provide and maintain for the sole use of the Independent Testing Laboratory adequate facilities for safe storage and proper curing of concrete test specimens on site for initial curing.

D. Concrete Sampling
   1. Obtain composite samples in compliance with ASTM C172. Select the trucks or batches of concrete to be tested on a random basis. Samples may be obtained at the truck.
   2. Obtain at least one composite sample for the first batch of concrete, and then for each 100 cubic yards, or fraction thereof, of each concrete mixture placed in any one day. When the total quantity of a given concrete mixture is less than 50 cubic yards, test the first batch of concrete, and at least one other batch.
   3. Determine slump of each sample in compliance with ASTM C143.
   4. Determine air content of each sample in compliance with ASTM C231.
   5. Determine temperature of each sample in compliance with ASTM C1064.
   6. Do not place concrete before slump, temperature, and air content tests demonstrate concrete is within acceptable limits.
   7. Conduct compressive strength tests of each sample in compliance with the following:
      a. Mold and cure three cylinders in compliance with ASTM C31. Record any deviations from the ASTM requirements in the test report.
      b. Test cylinders in compliance with ASTM C39. Test one specimen at seven days for information and two specimens at 28 days for acceptance, unless otherwise specified.

E. Evaluation and Acceptance of Tests
   1. Acceptance of Concrete
      a. The compressive strength tests results for acceptance of each sample shall be the average of the compressive strengths from the two specimens tested at 28 days.
      b. If one specimen in a sample shows evidence of improper sampling, molding, or testing, discard the specimen and consider the strength of the remaining cylinder to be the test result.
      c. If both specimens in a sample show any defects, both specimens shall be discarded.
d. Compressive strength tests will be considered acceptable if the average compressive strength of all 28-day specimens of three consecutive sample tests are equal to or exceed the specified 28-day compressive strength, and if no individual specimen compressive strength is more than 300 pounds per square inch below the specified 28-day compressive strength.

2. Test Cores: If concrete strength is not considered acceptable, or if there is a likelihood of low strength concrete, a significant reduction in load-carrying capacity or an absence of desired durability in the concrete, the Resident Engineer may require tests of cores drilled for determination of in-place strength.

a. Obtain and test specimens in conformance with ASTM C42. Take three cores from each area as directed by the Resident Engineer.

b. Test cores will be considered acceptable if the average of the three cores is equal to at least 85 percent of the specified 28-day compressive strength and no single core is less than 75 percent of the 28-day compressive strength. Locations represented by erratic core strengths may be retested at the direction of the Resident Engineer.

c. Fill core holes in conformance with the requirements of 03 35 00 Concrete Finishing.

d. If, as a result of these tests, it is determined that the specified concrete properties are not being obtained, the Contractor may order such changes in proportions or materials, or both, as may be necessary to secure the specified properties.

3. Repair or replace low-strength concrete as directed by the Resident Engineer. Concrete is defined as low-strength if concrete compressive strength tests and test cores do not meet the requirements for acceptable tests as described herein.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for the concrete placement, finishing, texturing, and curing of the track slab associated with the aerial guideways.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
B. Washington State Department of Transportation (WSDOT)
   1. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction

1.03 SUBMITTALS
A. Transmit: Qualifications for finishers
B. Transmit: Equipment/Tools List: Provide a list of equipment and tools to be used

1.04 QUALITY ASSURANCE
A. Finishers Qualifications: Finishers having completed work on at least two projects in the last five (5) years that have been accepted by WSDOT or Sound Transit without rework.

1.05 PRECONSTRUCTION MEETING
A. A preconstruction meeting shall be held 5 to 10 working days before placing concrete in accordance with WSDOT Standard Specifications Section 6-02.3(10)A.

PART 2 - PRODUCTS

2.01 MATERIALS - GENERAL
A. The materials used in the Work shall be as indicated on the Contract Drawings and conform to requirements in other Sections.

PART 3 - EXECUTION

3.01 GENERAL
A. The Work described in this Section shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(10), unless specified otherwise.

3.02 SCREED RAIL SUPPORTS
A. For screed rails, the Work shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(10)B.
3.03  FINISHING EQUIPMENT

A. The finishing equipment shall conform to the applicable provisions of WSDOT Standard Specifications Section 6-02.3(10)C.

B. Consideration shall be given due to the presence of plinth dowel bar or other objects on the deck.

3.04  CONCRETE PLACEMENT, FINISHING, AND TEXTURING

A. The concrete placement and finishing Work shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(10)D, except as noted below:

1. The concrete texturing work shall be performed in accordance with concrete finishing requirements as stated elsewhere in the Contract Documents.

2. The 10-foot straightedge requirement for flatness is not required.

3.05  CURING CONCRETE

A. The concrete surfaces shall be cured in accordance with the WSDOT Standard Specifications Section 6-02.3(11)B, except as noted below:

1. The wet curing requirement as described shall remain in place for at least 7 consecutive calendar days.

2. Curing concrete by spraying curing compound only is not allowed for guideway deck.
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for the finishing of formed and unformed concrete surfaces, including the repair of surface defects.

B. Governance: Requirements of this Section as applicable to concrete surfaces exposed to view shall govern over concrete forming and finishing.

C. Finishing treatments of floors, walls, ceiling, and other miscellaneous concrete surfaces include the following as scheduled and as indicated on the Contract Drawings.

1. CIP-1: Formed finish for exposed to public view structural elements
2. CIP-2: Unformed finish for aerial guideway track slab surfaces, at grade track slab surfaces, and plaza surfaces with integral color
3. CIP-3: Formed finish utilizing formliners
4. CIP-4: Broom finish medium to heavy for garage slabs

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. AASHTO M182 Burlap Cloth Made from Jute or Kenaf

2. American Concrete Institute (ACI):
   a. ACI 117 Standard Tolerances for Concrete Construction and Materials
   b. ACI 301 Specifications for Structural Concrete for Buildings
   c. ACI 302.1R Guide for Concrete Floor and Slab Construction
   d. ACI 305R Hot Weather Concreting
   e. ACI 306 Cold Weather Concreting
   f. ACI 308 Standard Practice for Curing Concrete
   g. ACI 347 Guide to Formed Concrete Surfaces
   h. ACI 503.4 Standard Specification for Repairing Concrete with Epoxy Mortars

3. American Society for Testing and Materials International (ASTM)
   a. ASTM C33 Specification for Concrete Aggregates
b. ASTM C150 Specification for Portland Cement

c. ASTM C171 Specifications for Sheet Materials for Curing Concrete

d. ASTM C309 Specification for Liquid Membrane-Forming Compounds for Curing Concrete

e. ASTM C881 Specification for Epoxy-Resin-Base Bonding Systems for Concrete

f. ASTM E 1155 Test Method for Determining Ff Floor Flatness and Fl Floor Levelness Numbers

4. Washington State Department of Transportation (WSDOT)
a. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
   
   1) Section 6-02.3(14)C Pigmented Sealer for Concrete Surfaces
   
   2) Section 9-08.3 Pigmented Sealer Materials for Coating of Concrete Surfaces, color Washington Gray.

1.03 SUBMITTALS

A. Pre-Approved Repair Procedures: Submit pre-approved procedures for minor spall repair and miscellaneous patching, major repairs, and crack repairs.

B. Transmit: Product Data: manufacturers’ product data for manufactured products specified and indicated.

C. Shop drawings, or diagrams to scale, that indicate the location in plan and elevation of all concrete finishes.

1.04 QUALITY ASSURANCE

A. Site Mock-Ups: Provide site mock-ups, at least 3 feet by 4 feet in size, of finishes of formed surfaces in exposed locations and of exposed slab finishes.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Placement and Finishing

1. Portland Cement: ASTM C150, Type II, of same brand as used in the work. Furnish white Portland cement where required to produce color matching color of surrounding concrete.

2. Aggregate:

   a. For Bonding Grout: ASTM C 33, washed clean sand passing a Number 30 sieve.

   b. For Patching Mortar: ASTM C 33, washed clean, graded fine aggregate of suitable size for areas to be repaired. Clean coarse aggregate up to Size Number 8 may be added for repair of larger pockets and voids.
3. Commercial Patching Mortar: Latex-modified Portland cement mortar may be furnished if appropriate for the use.

4. Skim Coat: Commercial polymer modified, Portland cement mortar for thin trowel application, recommended by manufacturer for smoothing and patching walls on projects where an ultra-smooth surface is desired.
   a. Basis of design product: Raeco Skimwall.

5. Sandblast: The finish of site area exposed concrete, flatwork elements (excluding the structure) shall be at a minimum "as cast" with a medium to heavy sand blast finish or approved equal finish. Final finish of exposed site concrete elements shall be established by means of site mock-up approved by Sound Transit.

B. Curing

1. Damp Curing Materials:
   a. Waterproof Sheet Materials: ASTM C171, waterproof paper with white paper face, polyethylene film pigmented white, or white burlap-polyethylene sheeting.
   b. Burlap: AASHTO M182, of class or weight suitable for the use and location. Do not use burlap where concrete is exposed to direct sunlight.

2. Curing Compound: ASTM C309, liquid membrane-forming curing compound, Type 1 for concrete not exposed to sunlight, and Type 1-D with white fugitive dye for concrete exposed to sunlight, Class A or B as appropriate for the use or location.

C. Sealer

1. Sealer Materials:
   a. Provide a clear, penetrating, waterborne, breathable water repellent for use on concrete. A ready-to-use, VOC < 50 g/l silane emulsion. Product to have min 40 percent silane in a water carrier.

D. Pigmented Sealer

1. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction, Section 9-08.3 Pigmented Sealer Materials for Coating of Concrete Surfaces.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. CIP-1: Formed Finish (Exposed to Public View Structural Elements).

1. Formwork: As specified in Section 03 11 00, Concrete Forming, for exposed to view surfaces.

2. Finishing Operations:
   a. Repair as specified in Section 03 30 00, Cast-In-Place Concrete.
   b. Apply skim coat or sandblast.
   c. Sponge finish.
d. Apply clear penetrating anti-graffiti sealer.

3. ACI 347 Formed Concrete Surface Category: CSC3, with Form Facing Category FC3. Work to meet approved mock up.

B. CIP-2: Unformed Finish (aerial guideway and at-grade track slab surfaces):
   1. Finish: Trowel and fine broom transverse to travel direction for permanently exposed top surfaces. Provide intentionally roughened surfaces under plinths and curbs.

C. CIP-3: Formed finish utilizing formliners (wall and abutment surfaces)
   1. Formwork: As specified in Section 03 11 00, Concrete Forming.
   2. Finishing Operations:
      a. Repair as specified in Section 03 30 00, Cast-In-Place Concrete.
      b. Apply skim coat or sandblast.
      c. Sponge finish.
      d. ACI 2347 Formed Concrete Finish Category: CSC3 with Surface Void Ratio meeting SVR3, Surface Irregularities meeting SI4 and Formed Facing Category FC3. Work to meet approved mock up.

D. CIP-4: Broom finish, medium to heavy for garage slabs

E. Other Formed Surface Finishes: After removing forms, finish each formed surface as noted below.
   1. Specified Finishes: For the surfaces specified below, provide the following surface finishes in conformance with ACI 301.
      a. Sump walls: Smooth form finish
   2. Unspecified Finishes: For surfaces not specified above, provide the following surface finishes in conformance with ACI 301.
      a. Concrete surfaces not exposed to public view: Rough-form finish.

F. Finishing Unformed Surfaces
   1. Placement:
      a. Place concrete at a rate that allows spreading, straight edging, and darbying or bullfloating before bleed water appears.
      b. Strike smooth the top of walls, buttresses, horizontal offsets, and other similar unformed surfaces and float them to a texture consistent with the finish of adjacent formed surface.
   2. Specified Finishes: For the surfaces specified below, provide the following surface finishes in conformance with ACI 301.
      a. Invert Slab: Scratched finish.
      b. Topping Slab: Troweled finish;
3. Unspecified Finishes: for surfaces not specified above, provide the following surface finishes in conformance with ACI 301.
   a. Surfaces to receive bonded cementitious materials and tile: Trowel and fine broom finish.
   b. Walks; drives; steps; ramps; and surfaces intended to receive waterproofing, roofing, insulation, or sand-bed terrazzo: Floated finish.
   c. Interior slabs and flatwork to be exposed in the completed structure and for slabs to receive resilient floor coverings: Troweled finish.

3.02 FIELD QUALITY CONTROL
   A. Finishes: Conform to applicable requirements of ACI 301.
   B. Tolerances:
      1. Conform to the applicable requirements of ACI 301. For parts of the structures not covered by ACI 301, conform to the applicable requirements of ACI 117.

3.03 CORRECTIVE MEASURES
   A. Remedy for out-of-tolerance work:
      1. Designated Floor Sections measuring at or above both of the specified Minimum Local F-Numbers (MLV) shall be accepted for tolerance compliance as constructed.
      2. Floor Sections measuring below the specified MVL F-Number shall be ground and/or re-topped as directed by the Resident Engineer.
         a. For the purposes of this paragraph, a Floor Section shall be any rectangular area of approximately 1500 square feet.

3.04 PROTECTION
   A. Protect exposed concrete surfaces as required preventing damage from impact or strains.

3.05 REPAIR OF SURFACE DEFECTS
   A. General
      1. Repair all surface defects greater than 1 inch. For all surfaces exposed to view in stations, repair defects greater than a dime size.
      2. Repair tie holes and surface defects immediately after removing formwork and before curing.
      3. Where the surface is to be textured, repair tie holes and surface defects before texturing.
      4. Manufactured repair materials may be used in lieu of site-mixed repair materials. Apply manufactured repair materials in conformance with manufacturer’s printed directions.
      5. Repair concrete damage caused by construction activities, such as accidental equipment impact, temporary anchor bolts and construction equipment connections.
B. Site-Mixed Repair Materials

1. Bonding grout: Mix one part cement to one part fine sand to the consistency of thick cream.

2. Patching mortar
   a. Use same materials as the concrete to be patched with no coarse aggregate. Do not use more than one part cement to 2-1/2 parts sand.
   b. For repairs in exposed concrete, substitute white portland cement for a portion of the gray portland cement to produce a mix matching the surrounding concrete color when dry. Determine the proportion of white portland cement by trial mixes and test areas, prior to repair of actual defective areas.

C. Repair of Tie Holes

1. Plug all tie holes with the exception of tie holes as described in Section 03 35 00.

2. If portland cement patching mortar is used for plugging, clean and dampen tie holes before application.

D. Repair of Surface Defects Other Than Tie Holes

1. Outline defect with 1/2-inch to 3/4-inch deep saw cut. Remove all concrete within the sawcut to sound concrete. If chipping is required, leave chipped edges perpendicular to the surface or slightly undercut. Do not feather edges.

2. Dampen area to be patched plus a 6-inch band around the perimeter. Brush bonding grout thoroughly into the surface.

3. When bond coat begins to lose water sheen, apply patching mortar and thoroughly consolidate into place. Strike off mortar, leaving slightly higher than surrounding surface to permit shrinkage.

4. Finish the patch after 1 hour. Keep patch damp for seven days.

E. Removal of surface stains and deposits

1. Remove stains, rust, efflorescence, and surface deposits.

END OF SECTION
SECTION 03 41 00
PRECAST GIRDER GENERAL

1.01 SUMMARY

A. This Section includes requirements for the fabrication and erection of precast concrete components (prestressed I girders and tub girders) and structures associated with aerial guideways and stations as indicated in the Contract Documents.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Washington State Department of Transportation (WSDOT)
   a. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
   b. WSDOT Bridge Design Manual LRFD, M 23-50

2. American Welding Society (AWS)
   a. AWS D1.1 Structural Welding Code – Steel
   b. AWS D1.4 Structural Welding Code - Reinforcing Steel

3. Precast/Prestressed Concrete Institute (PCI)
   a. PCI MNL-116 Quality Control for Plants and Production of Structural Precast and Prestressed Concrete Products
   b. PCI MNL-117 Manual for Quality Control for Plants and Production of Architectural Precast Concrete Products
   c. PCI MNL-120 PCI Design Handbook - Precast and Prestressed Concrete
   d. PCI MNL-123 Design and Typical Details of Connections for Precast and Prestressed Concrete
   e. PCI MNL-135 Tolerance Manual for Precast and Prestressed Concrete Construction

1.03 SUBMITTALS

A. Transmit: Product Data: Manufacturer’s information on accessory products, including pigments, admixtures, inserts and plates.

B. Shop Drawings: Shall be in accordance with WSDOT Standard Specifications Section 6-02.3(25)A.

C. Self-Consolidating Concrete for Precast Units: Submittals shall be in accordance with WSDOT Standard Specifications Section 6-02.3(27)A.

D. Provide details of all connections, joints, accessories, cast inserts, and openings.
E. Quality Control Plan: in accordance with requirements of Plant Quality System Manual in PCI MNL-116. The precast concrete production cannot proceed prior to Sound Transit approval of the Quality Control Plan.

F. Quality Assurance

1. Perform the work of this Section in accordance with PCI MNL-116, PCI MNL-117, PCI MNL-120, PCI MNL-123, PCI MNL-135, ACI 301, ACI 318, and CRSI Manual of Standard Practice. Perform welding in accordance with AWS D1.1/D1.1M.

2. Maintain one copy of each document on site.

G. Fabricator Qualifications:

1. Firm having at least ten (10) years of documented experience in production of precast concrete of the type required.

2. Plant certified under Precast/Prestressed Concrete Institute Plant Certification Program.

3. Employ a full time on-site Quality Control Manager certified by PCI for Plant Quality Personnel, Level II.

4. Approved by WSDOT as a Certified Concrete Fabricator prior to the start of production.


I. Welder: Certified within previous 12 months in accordance with AWS D1.1 and AWS D1.4.

1.04 DELIVERY STORAGE AND HANDLING

A. Handling and Storage: In accordance with WSDOT Standard Specifications Section 6-02.3(25)L.

B. Delivery: In accordance with WSDOT Standard Specifications Section 6-02.3(25)M.

C. Deliver precast units to project site in such quantities and at such times to ensure continuity of installation.

D. Protect units to prevent staining, chipping, or spalling of concrete.

E. Mark units with date of production in location that will be concealed after installation.

PART 2 - PRODUCTS

2.01 MATERIALS - GENERAL

A. The materials used in the Work shall be as indicated on the Contract Drawings and conform to the applicable provisions of WSDOT Standard Specifications Section 6-02, unless specified otherwise.
2.02 FABRICATION OF GIRTERS

A. Fabrication of girders shall be in accordance with applicable provisions of WSDOT Standard Specifications Section 6-02.3(25).

PART 3 - EXECUTION

3.01 GENERAL

A. The Work described in this Section shall be performed in accordance with the applicable provisions of WSDOT Standard Specifications Section 6-02, unless specified otherwise.

3.02 PRESTRESSED CONCRETE GIRDER

A. General: For prestressed concrete girders, the Work shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(25).

B. The erection of the prestressed concrete girders shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(25)N.

3.03 CONCRETE FOR PRECAST UNITS

A. General: For concrete for precast units, the Work shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(27).

3.04 INSPECTION:

A. General: For inspection of precast units, the Work shall be performed in accordance with WSDOT Standard Specifications Section 6-02.3(25)

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing nonshrink grouts as follows:

1. Furnishing, mixing, and placing nonshrink, nonmetallic, noncorrosive cementitious grout.

2. Furnishing, mixing, and placing nonshrink, nonmetallic, noncorrosive epoxy grout.

3. Not applicable to Non-Shrink Grout for Post-Tensioning Applications.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Concrete Institute (ACI):
   a. ACI 503.2 Specification for Bonding Plastic Concrete to Hardened Concrete with a Multi-Component Epoxy Adhesive

   b. ASTM C157 Test Method for Length Change of Hardened Hydraulic Cement Mortar and Concrete
   c. ASTM C579 Standard Test Method for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes
   d. ASTM C827 Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures
   e. ASTM C881 Specification for Epoxy-Resin-Base Bonding Systems for Concrete
   f. ASTM C1090 Test Method for Measuring Changes in Height of Cylindrical Specimens from Hydraulic-Cement Grout
   g. ASTM C1107 Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrinkable)
   h. ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
   i. ASTM D395 Standard Test Methods for Rubber Property—Compression Set

3. United States Army Corps of Engineers:
   a. CRD-C620 Standard Method of Sampling Fresh Grout
   b. CRD-C621 Corps of Engineers Specification for Nonshrink Grout

1.03 DEFINITIONS:
   A. Nonshrink grout: A mortar or grout that does not shrink in the plastic state, is dimensionally stable in the hardened state, and bonds permanently to a clean baseplate and concrete substrate.

1.04 SUBMITTALS
   A. Transmit: Product Data: Submit manufacturer's product data and installation instructions.
   B. Transmit: Certification: Submit certificates of compliance or laboratory test reports that indicate the following:
      1. Materials used in the grout are free from metallic components and corrosion-producing elements.
      2. Materials meet specified shrinkage and compressive strength requirements.

1.05 PROJECT CONDITIONS:
   A. Follow manufacturer's instructions for storage, handling, placing and curing.

PART 2 - PRODUCTS

2.01 MATERIALS
   A. Cementitious Grout: Provide nonshrink, nonmetallic, noncorrosive cement-based grout conforming to the following requirements:
      2. Expansion: 0.4 percent maximum at 3, 14, and 28 days. No displacement when tested in accordance with ASTM C157.
      3. Shrinkage at 28 days: none (0.00 shrinkage when tested in accordance with ASTM C827).
      4. Compressive strength, minimum:
         a. At one day: 1000 pounds per square inch (psi)
         b. At three days: 2500 psi
         c. At seven days: 3500 psi
         d. At 28 days: 5000 psi
      5. Initial setting time, after addition of water: approximately one hour at 70 degrees F.
6. Provide nonsag trowelability or flowability as necessary for the particular application.

B. Water: Clean and potable, free of impurities detrimental to grout.

C. Epoxy Grout: Provide nonshrink, nonmetallic, noncorrosive epoxy grout conforming to the following requirements:
   1. Grout shall be manufactured specifically for use in supporting heavy loads.
   2. Expansion: No displacement when tested in accordance with ASTM C827 and ASTM C157, modified procedures.
   3. Shrinkage at 28 days: None (0.00 shrinkage when tested in accordance with ASTM C827 modified procedure using a specific gravity of indicator ball of approximately 1.0) with a minimum effective bearing area (EBA) of 95 percent.
   4. Compressive strength, minimum: 10,000 psi at 7 days.
   5. Initial setting time: Approximately one hour at 70 degrees F.
   6. Provide flowable consistency as necessary for the particular application.
   7. Epoxy grouts which are volatile and which give off noxious fumes are not acceptable.

D. Epoxy Adhesive: ASTM C881, Type V, epoxy-based bonding agent.

E. Elastomeric Grout:
   1. Tensile Strength: ASTM D638
   2. Dynamic Deflection: ASTM D5992
   3. Dielectric Strength: ASTM D149

2.02 SOURCE QUALITY CONTROL

A. Inspections and Tests: Perform visual inspections, and shrinkage tests using an approved independent test laboratory, and strength tests as necessary to verify performance requirements of grout. Sample and test grout in conformance with applicable ASTM or CRD-620 requirements.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prepare concrete surfaces to receive grout by chipping, sandblasting, water blasting, or other accepted methods to remove defective concrete, laitance, dirt, oil, grease, and other foreign matter to achieve sound, clean, and roughened concrete surfaces; in accordance with the manufacturer's requirements.

B. Cover concrete areas with protective waterproof covering until ready to place grout.

C. Remove foreign matter from surfaces to be in contact with grout. Clean contact steel surfaces as necessary by wire brushing and wiping dust clean.

D. Align and level components to be grouted, and maintain in final position until grout placement is complete and accepted.
E. Install forms for grout about the columns and other spaces to be grouted.

F. Remove protective waterproof covering and clean contaminated surfaces immediately before grouting.

G. Provide air-relief holes in large baseplates and in baseplates where underneath obstructions may cause air entrapment.

H. Saturate concrete surfaces with clean water, and remove excess water immediately before grouting.

I. Where necessary or appropriate for better bond, epoxy adhesive may be applied to clean, dry substrate surfaces in accordance with applicable requirements of ACI 503.2.

3.02 CONSTRUCTION

A. Mixing

1. Mix grout ingredients in accordance with the respective manufacturer’s instructions and recommendations. Mix grout materials in proper mechanical mixers.

2. Mix grout as close to work area as possible.

B. Installation

1. Place grout in accordance with the manufacturer’s published instructions. Pour grout from one side only until grout rises at least one inch above the plate on opposite side of said plate. Strapping and plunging or other recommended method may be used to force grout to flow under the entire area.

C. Neatly trowel edges of grout base, tapered at an angle of 60 degrees when measured from the horizontal, or as indicated.

1. Do not remove leveling shims for at least 48 hours after grout has been placed.

2. After shims have been removed, if used, fill voids with grout, packing the material with a suitable tool.

3. Do not use grout that has begun to set or if more than one hour has elapsed after initial mixing.

D. Curing

1. Cure cementitious grout as recommended by the grout manufacturer.

2. Cure epoxy grout as recommended by the grout manufacturer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes requirements for (a) standard concrete unit masonry, (b) mortar and grout, (c) steel reinforcement and anchorage, (d) accessories, and (e) masonry installation.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents as adopted by the authorities having jurisdiction (AHJ).

1. The Masonry Society (TMS)
   a. TMS 402 Building Code Requirements for Masonry Structures
   b. TMS 602 Specification for Masonry Structures

2. ASTM International (ASTM)
   a. ASTM A615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
   b. ASTM C90 Standard Specification for Loadbearing Concrete Masonry Units
   c. ASTM C140 Standard Test Methods of Sampling and Testing Concrete Masonry Units and Related Units
   d. ASTM C144 Standard Specification for Aggregate for Masonry Mortar
   e. ASTM C150/ Standard Specification for Portland Cement
   f. ASTM C207 Standard Specification for Hydrated Lime for Masonry Purposes
   g. ASTM C270 Standard Specification for Mortar for Unit Masonry
   h. ASTM C404 Standard Specification for Aggregates for Masonry Grout
   i. ASTM C476 Standard Specification for Grout for Masonry

3. Underwriters Laboratories Inc. (UL)
   a. UL Fire Resistance Directory (FRD)

1.03 SUBMITTALS

A. Transmit: Product Data: Masonry units, fabricated wire reinforcement, mortar, and masonry accessories.
B. Shop Drawings: Shop drawing will include individual CMU wall elevations including the following work.

1. Indicate reinforcement fabrication, bending, and placement. Include bar schedules, stirrup spacing schedules, bending and arrangement diagrams for reinforcement.

2. Indicate height of walls, including top and bottom of all raked walls. Include location, length and design of bond beams.

3. Indicate location and provisions required for attachment of work included in other sections and the Contract Drawings. Work indicated will include all penetrations and openings for mechanical, electrical and systems equipment, ducts and conduit or piping.

C. Transmit: Manufacturers’ Certificate: Certify that masonry units, grout and mortar mixes meet or exceed specified requirements. Include test results or International Code Council (ICC) Evaluation Reports for all specified items required to meet specific standards.

D. Transmit: Samples: Four (4) samples of each type of masonry used to illustrate color, texture, and extremes of color range.

1.04 QUALITY ASSURANCE

A. Comply with provisions of the Quality Assurance Program in TMS 402 except where exceeded by requirements of the contract documents. Maintain copy of document on project site.

B. Fire-Rated Assemblies: Conform to UL FRD and any applicable local authority having jurisdiction for fire-resistive requirements for fire-rated masonry construction.

1.05 MOCK-UP

A. For each construction site, construct a masonry wall as a mock-up panel of reinforced ground-face masonry sized 8 feet long by 6 feet high, which includes mortar and accessories, structural backup, wall openings, flashings, and typical strike joints and patterns, including a typical control joint with proposed colored sealant.

B. Construct mock-up panel and obtain acceptance prior to construction of any masonry walls.

C. Locate where directed by Resident Engineer.

D. Accepted mock-up may remain as part of the Work.

1.06 DELIVERY STORAGE AND HANDLING

A. Deliver, handle, and store masonry units by means that will prevent mechanical damage and contamination by other materials and in compliance with manufacturer’s written instructions.

1.07 PROJECT CONDITIONS

A. Environmental Requirements

1. Comply with adverse weather construction requirements contained in ACI 530.1/ASCE 6/TMS 602 except where exceeded by requirements of the contract documents.
PART 2 - PRODUCTS

2.01 MATERIALS

A. CONCRETE MASONRY UNITS (CMU)

1. Standard Concrete Block: CMU-1 nonstructural and CMU-2 structural. Comply with referenced standards and as follows:

   a. Sizes: Provide standard hollow core units with nominal face dimensions of 16 inches by 8 inches and nominal depth as indicated on Contract Drawings.

   b. Special Shapes: Provide non-standard blocks configured for corners, bond beams, lintels, headers, sloped caps, control joint edges (sash blocks), and other detailed conditions.

   c. Load-Bearing Units (Typical): ASTM C90, Type 1, normal or medium weight with a minimum compressive strength as noted on Contract Drawings.

   d. Concrete block finishes and colors where called for in drawings;

      1) CMU-2a: Ground faced finish, color to match approved Mutual Materials “Khaki”.

      2) CMU-2b: Split faced finish, color to match Mutual Materials approved “Mountain Brown”.

2. Decorative Concrete Block: CMU-3 ground faced finish and CMU-4 split faced finish. Comply with referenced standards and as follows:

   a. Sizes: Provide standard hollow core units with nominal face dimensions of 16 inches by 8 inches and nominal depth as indicated on Contract Drawings.

   b. Special Shapes: Provide non-standard blocks configured for corners, bond beams, lintels, headers, sloped caps, control joint edges (sash blocks), and other detailed conditions.

   c. Load-Bearing Units (Typical): ASTM C90, Type 1, normal or medium weight with a minimum compressive strength as noted on Contract Drawings.

   d. Concrete block finishes and colors where called for in drawings;

      1) CMU-3a: Ground faced finish, color to match approved Mutual Materials “Khaki”.

      2) CMU-3b: Ground faced finish, color to match approved Mutual Materials “Natural”.

      3) CMU-4a: Split faced finish, color to match Mutual Materials approved “Charcoal”.

      4) CMU-4b: Split faced finish, color to match Mutual Materials approved “Mountain Brown”.

B. Mortar and Grout Materials
1. Portland Cement: ASTM C150, Type I, II or III.
2. Hydrated Lime: ASTM C207, Type S.
4. Mortar Aggregate: ASTM C144; washed aggregate consisting of natural sand or crushed stone.
5. Water: Clean and not detrimental to mortar mixture.

C. Reinforcement and Anchorage
1. Reinforcing Steel: Type and grade as specified in concrete reinforcing in the Contract Documents.
2. Flexible Anchors: 2-piece anchors that permit differential movement between masonry and building frame, sized to provide not more than 1 inch and not less than 1/2 inch of mortar coverage from masonry face (no exceptions).

D. Embedded Flashings:
1. Through-Wall Metal Flashing: Provide metal flashing complying with sheet metal flashing and trim as stated elsewhere in the Contract Documents.

E. Flexible Flashing: For flashing not exposed to the exterior:
1. Rubberized-Asphalt Flashing: Composite flashing product consisting of a pliable, adhesive rubberized-asphalt compound, bonded to a high-density, cross-laminated polyethylene film to produce an overall thickness of not less than 0.030 inch.
   a. Products:
      1) Carlisle Coatings & Waterproofing; CCW-705-TWF Thru-Wall Flashing
      2) Dayton Superior Corporation, Dur-O-Wal Division; Dur-O-Barrier-44
      3) Grace Construction Products, a unit of W. R. Grace & Co. - Conn.; Perm-A-Barrier Wall Flashing
      4) Heckmann Building Products Inc.; No. 82 Rubberized-Asphalt Thru-Wall Flashing
      5) Hohmann & Barnard, Inc.; Textroflash
      6) Polyguard Products, Inc.; Polyguard 300
      7) Polytite Manufacturing Corp.; Poly-Barrier Self-Adhering Wall Flashing

F. Accessories
1. Preformed Control Joints: Rubber material. Provide with corner and tee accessories, fused joints.
   a. Manufacturers:
1) Dur-O-Wal  
2) Hohmann & Barnard, Inc.; Product as detailed  
3) Masonry Reinforcing Corporation of America

2. Joint Filler: Closed cell polyvinyl chloride; oversized 50 percent to joint width; self-expanding; 6 inches wide by the maximum lengths available.  
   a. Manufacturers:  
      1) Dur-O-Wal; Product as detailed  
      2) Hohmann & Barnard, Inc.; Product as detailed  
      3) Masonry Reinforcing Corporation of America

3. Weep/Vent Products: Use one of the following, unless otherwise indicated:  
   a. Mesh Weep/Vent: Free-draining mesh; made from polyethylene strands, full height and width of head joint and depth 1/8 inch less than depth of outer wythe; in color selected from manufacturer's standard.

   b. Products:  
      1) Mortar Net USA, Ltd.; Mortar Net Weep Vents or approved equal.

4. Cavity Drainage Material: Free-draining mesh, made from polymer strands that will not degrade within the wall cavity.  
   a. Provide strips full-depth of cavity and 10 inches wide, with dovetail shaped notches 7 inches deep that prevent mesh from being clogged with mortar droppings.

   b. Products:  
      1) Advanced Building Products Inc.; Mortar Break II.  
      2) Archovations, Inc.; CavClear Masonry Mat  
      3) Dayton Superior Corporation, Dur-O-Wal Division; Polytite MortarStop  
      4) Mortar Net USA, Ltd.; Mortar Net.

5. Cleaning Solution: Non-acidic, not harmful to masonry work or adjacent materials.


2.02 MIXES

A. Mortar and Grout Mixes  
1. Mortar for Unit Masonry: ASTM C270 Standard Specification for Mortar for Unit Masonry. Use Type N for exterior, above grade, or load bearing condition. Refer to the contract documents for specific type and strength.
2. Grout: ASTM C476. Consistency required to fill completely volumes indicated for grouting; fine grout for spaces with smallest horizontal dimension of 2 inches or less; coarse grout for spaces with smallest horizontal dimension greater than 2 inches. Refer to the contract documents for additional requirements.

3. Mixing: Use mechanical batch mixer and comply with referenced standards.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that field conditions are acceptable and are ready to receive masonry.

B. Verify that related items provided under other sections are properly sized and located.

C. Verify that built-in items are in proper location, and ready for roughing into masonry work.

D. Do not proceed until unsatisfactory conditions have been corrected.

3.02 PREPARATION

A. Direct and coordinate placement of metal anchors supplied for installation under other Sections.

B. Place reinforcement and ties in grout spaces prior to grouting.

C. Provide temporary bracing during installation of masonry work. Maintain in place until building structure provides permanent bracing.

3.03 INSTALLATION

A. Comply with referenced standards.

B. Leave openings for equipment to be installed. Coordinate with other trades.

3.04 COURSING

A. Establish lines, levels, and coursing indicated. Protect from displacement.

B. Maintain masonry courses to uniform dimension. Form vertical and horizontal joints of uniform thickness.

C. Concrete Masonry Units:
   1. Bond: Running.
   2. Coursing: One unit and one mortar joint to equal 8 inches.
   3. Mortar Joints: Concave. Joints that will be concealed by other construction (such as furred gypsum board) may be struck flush.

3.05 PLACING AND BONDING

A. Lay out walls in advance for accurate spacing of surface bond patterns with uniform joint widths and for accurate location of openings, joints, returns, and offsets. Avoid the use of less than half-size units at corners, jambs, and other locations.

B. Lay hollow masonry units with face shell bedding on head and bed joints.
C. Buttering corners of joints or excessive furrowing of mortar joints is not permitted.

D. Remove excess mortar and mortar smears as work progresses.

E. Interlock intersections and external corners.

F. Do not shift or tap masonry units after mortar has achieved initial set. Where adjustment must be made, remove mortar and replace.

G. Perform job site cutting of masonry units with proper tools to provide straight, clean, unchipped edges. Prevent broken masonry unit corners or edges.

H. During erection, cover tops of walls, projections, and sills with waterproof sheeting at the end of each day's work. Cover partially completed masonry when construction is not in progress. Extend cover a minimum of 24 inches down both sides and hold securely in place.

I. Stain Prevention: Prevent grout, mortar, and soil from staining the face of masonry to be left exposed or painted. Remove immediately all grout, mortar, and soil that comes into contact with such masonry.
   1. Protect base of walls from rain-splashed mud and mortar splatter by means of coverings spread on wall surface and on the ground.
   2. Protect sills, ledges, and projections from mortar droppings.

J. Stopping and Resuming work: In each course, rack back as required, clean exposed surfaces of set masonry, wet clay masonry units if required, and remove loose units prior to laying fresh masonry.

K. Isolate masonry partitions from vertical structural framing members with a control joint.

L. Isolate top joint of masonry partitions from horizontal structural framing members and floor slabs or decks with compressible joint filler or firestopping as required.

3.06 REINFORCEMENT AND ANCHORAGE - GENERAL

A. Fasten anchors to structural framing and embed in masonry joints as masonry is laid. Place reinforcement, wall ties and anchors in accordance with the sizes, types and locations indicated on the Contract Drawings, and as specified. Do not place dissimilar metals in contact with each other.

3.07 FLASHING, WEEP HOLES, CAVITY DRAINAGE, AND VENTS

A. General: Install embedded flashing and weep holes in masonry at shelf angles, lintels, ledges, other obstructions to downward flow of water in wall, and where indicated.

B. Install flashing as follows, unless otherwise indicated:
   1. Prepare masonry surfaces so they are smooth and free from projections that could puncture flashing. Where flashing is within mortar joint, place through-wall flashing on sloping bed of mortar and cover with mortar. Before covering with mortar, seal penetrations in flashing with adhesive, sealant, or tape as recommended by flashing manufacturer.
   2. At lintels and shelf angles, extend flashing a minimum of 6 inches into masonry at each end. At heads and sills, extend flashing 6 inches at ends and turn up not less than 2 inches to form end dams.
3. Install metal flashing termination beneath flexible flashing at exterior face of wall. Stop flexible flashing 1/2 inch back from outside face of wall and adhere flexible flashing to top of metal flashing termination.

4. Cut flexible flashing off flush with face of wall after masonry wall construction is completed.

C. Install weep holes in head joints in exterior wythes of first course of masonry immediately above embedded flashing and as follows:
   1. Use specified weep/vent products to form weep holes.
   2. Space weep holes 24 inches on center, unless otherwise indicated.

D. Place cavity drainage material in cavities to comply with configuration requirements for Cavity Drainage Material Article in Part 2.

3.08 LINTELS
A. Provide reinforced concrete or reinforced concrete masonry lintels as detailed or scheduled on Contract Drawings.
B. All lintels to maintain minimum 8-inch bearing on each side of opening.

3.09 GROUTED COMPONENTS
A. Splices: Lap 24 bar diameters minimum.
B. Support and secure reinforcing bars from displacement. Maintain position within 1/2 inch of dimensioned position.
C. Place and consolidate grout fill without displacing reinforcing.
D. Do not place grout until entire height of masonry to be grouted has attained sufficient strength to resist grout pressure.

3.10 CONTROL JOINTS
A. Form control joint using sash blocks on both sides of joint.
B. Install preformed control joint device in continuous lengths. Seal butt and corner joints in accordance with manufacturer's instructions.
C. Size control joint to match typical mortar joint width.

3.11 BUILT-IN WORK
A. As work progresses, install built-in metal door frames and other items to be built into the work and furnished under other sections.
B. Install built-in items plumb, level, and true to line.
C. Bed anchors of metal door and glazed frames in adjacent mortar joints.
   1. Fill adjacent masonry cores with grout minimum 12 inches from framed openings.
D. Do not build into masonry construction organic materials that are subject to deterioration.

3.12 TOLERANCES
A. Maximum Variation from Unit to Adjacent Unit: 1/16 inch.
B. Maximum Variation from Plane of Wall: 1/4 inch in 10 feet and 1/2 inch in 20 feet or more.
C. Maximum Variation from Plumb: 1/4 inch per story non-cumulative; 1/2 inch in two stories or more.
D. Maximum Variation from Level Coursing: 1/8 inch in 3 feet and 1/4 inch in 10 feet; 1/2 inch in 30 feet.
E. Maximum Variation of Joint Thickness: 1/8 inch in 3 feet.
F. Maximum Variation from Cross Sectional Thickness of Walls: 1/4 inch.

3.13 CUTTING AND FITTING
A. Cut and fit for chases, pipes, conduit, and structure. Coordinate with other sections of work to provide correct size, shape and location.
B. Obtain approval prior to cutting or fitting masonry work not indicated or where appearance or strength of masonry work may be impaired.

3.14 FIELD QUALITY CONTROL
A. Concrete Masonry Unit Tests: Test each variety of concrete unit masonry in accordance with ASTM C140 for conformance to requirements in Section 01 45 00 Quality Assurance / Quality Control.

3.15 CLEANING
A. Remove excess mortar and mortar droppings.
B. Replace defective mortar. Match adjacent work.
C. Clean soiled surfaces with cleaning solution.
D. Use non-metallic tools in cleaning operations.

3.16 PROTECTION OF FINISHED WORK
A. Without damaging completed work, provide protective boards at exposed external corners, which are subject to damage by construction activities.

END OF SECTION
SECTION 05 05 13
SHOP-APPLIED COATINGS FOR METAL

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for galvanizing where indicated for steel items.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:

1. American Galvanizers Association, Inc. (AGA)
   a. AGA Inspection Manual for Hot-Dip Galvanized Products

   a. ASTM A123/A123M - Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   b. ASTM A143/A143M - Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
   c. ASTM A384/A384M - Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
   d. ASTM A780/A780M - Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
   e. ASTM B6 - Standard Specification for Zinc

3. Society for Surface Protective Coatings (SSPC)
   a. SP6 Commercial Blast Cleaning
   b. SP8 Pickling

1.03 DEFINITIONS
A. Hot-dip galvanizing: Dipping steel members and assemblies into molten zinc, which results in zinc coating fusing permanently with base steel material for lasting, or long-term corrosion protection.

1.04 SUBMITTALS
A. Transmit Certification: Furnish certification for the following, signed by the galvanizer:
   1. Membership in American Galvanizers Association Inc.
   2. Materials used in galvanizing and repair
   3. Methods used in galvanizing and repair
B. Coordination Drawings: To safeguard against distortion, furnish to the galvanizer steel fabricator's shop drawings of the following:

1. Non-standard fabrications
2. Tubular fabrications
3. Fabrications involving any dimension that exceed the size of the galvanizer's kettle
4. Fabrications involving materials of different thicknesses

C. Reports showing results of all inspections and tests.

D. Product Data

1.05 QUALITY ASSURANCE

A. Engage a galvanizing firm with a current membership in the American Galvanizers Association Inc. (AGA).

B. Inspect and test galvanized fabrications in accordance with ASTM A123 for the following:

1. Visual examination of samples and finished products
2. Thickness of coating
3. Adhesion

C. Mark all galvanized material with the galvanizer's stamp.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle galvanized fabrications in a manner that prevents damage to the item and its galvanizing.

PART 2 - PRODUCTS

2.01 GALVANIZING MATERIALS

A. Zinc for Galvanizing: ASTM B6

B. Galvanizing Repair Paint: A three-part system using an organic zinc-rich primer, an epoxy or urethane intermediate coat, and a urethane topcoat. If the final finish will be a high performance coating confirm compatibility with HPC-3 coating in accordance with Section 09 96 00.

1. Non-Structural, Non-Load-Bearing Items Not Exposed To Weather:
   a. Zinc-Rich Paints:
      1) Zinc-Dust Content: Dried film shall contain 94 percent minimum of zinc-dust by weight.
      2) Acceptable Manufacturers:
b) ZRC Galvilite by ZRC Worldwide, Marshfield, MA

2. Structural, Load-Bearing Items And Items Exposed To Weather:
   a. Zinc-Based Solders, Powder, Or Rod:
      1) Zinc-Cadmium solder with liquidus temperature range from 518 to 527 deg F, or
      2) Zinc-Tin-Lead alloy with liquidus temperature range from 446 to 500 deg F.
   b. Sprayed Zinc: Wire, ribbon, or powdered zinc suitable for process.

PART 3 - EXECUTION

3.01 GALVANIZING

A. Preparation
   1. Complete fabrications to the greatest extent possible prior to galvanizing.
   2. Mask areas that are to be field welded or that are to be shop welded to ungalvanized members to a distance of one inch from the weld line prior to galvanizing.
   3. Clean all surfaces in accordance with SSPC SP6, Commercial Blast Cleaning (1 to 2 mil anchor pattern), as minimum.
   4. Pickle all surfaces in accordance with SSPC SP8, Pickling.

B. Application
   1. Hot-dip galvanize in accordance with ASTM A123. Mix the galvanizing bath to contain 0.05 to 0.09 percent nickel by weight. Apply galvanizing in the weights and thicknesses specified.
   2. Safeguard against steel embrittlement in accordance with ASTM A143.
   3. Safeguard against warpage or distortion in accordance with ASTM A384. Notify the Resident Engineer of potential warpage problems that require modification in design before proceeding with fabrications.
   4. Do not treat with quenching or chromate conversion if the galvanized steel shall be painted.

C. Repair
   1. Grind rough areas to produce a uniform surface.
   2. Repair defects and coat masked areas in accordance with ASTM A780. The extent of repair area shall be agreed upon by all contracting parties.

3.02 FIELD QUALITY CONTROL AND REPAIR

A. Galvanized Surfaces:
   1. Apply galvanizing repair paint or other methods in accordance with ASTM A780.
2. Apply repair materials immediately after surface preparation is complete.

3. Take measurements, with either magnetic or electromagnetic gauge, to ensure applied coating thickness is as specified.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for welding and bolting of structural steel and metal fabrications, and welding of sheet steel. This Section also includes qualification of welders and welding procedures, inspections and tests of welding and bolting.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Institute of Steel Construction (AISC)
   a. AISC 303 Code of Standard Practice for Steel Buildings and Bridges

2. American Society for Nondestructive Testing (ASNT)
   a. Recommended Practice Number SNT-TC-1A

3. ASTM International (ASTM)
   a. ASTM A108 Standard Specification for Steel Bars, Carbon and Alloy, Cold-Finished
   b. ASTM A153/A153M Standard Specification for Zinc-Coating (Hot-Dip) on Iron and Steel Hardware
   c. ASTM A307 Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 psi Tensile Strength
   d. ASTM F3125 / F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength
   e. ASTM A563 Standard Specification for Carbon and Alloy Steel Nuts
   f. ASTM E94 / E94M Standard Guide for Radiographic Examination Using Industrial Radiographic Film
   g. ASTM E164 Standard Practice for Contact Ultrasonic Testing of Weldments
   h. ASTM E165 Standard Practice for Liquid Penetrant Examination for General Industry
   i. ASTM E709 Standard Guide for Magnetic Particle Testing
   j. ASTM E1032 Standard Test Method for Radiographic Examination of Weldments
k. ASTM F436 / F436M Standard Specification for Hardened Steel Washers Inch and Metric Dimensions

l. ASTM F844 Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use

m. ASTM F959 / F959M Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners, Inch and Metric Series

n. ASTM F1554 Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

o. ASTM F3125 / F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength, Inch and Metric Dimensions

4. American Welding Society (AWS)
   a. ANSI/AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination
   b. ANSI/AWS A3.0 Standard Welding Terms and Definitions
   c. ANSI/AWS A5 Series Filler Metal Procurement Guidelines
   d. ANSI/AWS B1.10 Guide for the Nondestructive Examination of Welds
   e. ANSI/AWS D1.1/D1.1M Structural Welding Code - Steel
   f. ANSI/AWS D1.3/D1.3M Structural Welding Code - Sheet Steel
   g. ANSI/AWS D1.5M/D1.5 Bridge Welding Code
   h. ANSI/AWS D1.6/D1.6M Structural Welding Code – Stainless Steel
   i. ANSI/AWS D1.8/D1.8M Structural Welding Code – Seismic Supplement
   j. AWS QC1 Standard for AWS Certification of Welding Inspectors

5. Research Council on Structural Connections (RCSC)
   a. Specification for Structural Joints Using ASTM A325 or A490 Bolts

6. Washington Association of Building Officials (WABO)
   a. WABO Welder and Welding Operator Performance Qualification Standard (No. 27-13)

7. Washington Department of Transportation (WSDOT)
   a. WSDOT Standard Specifications for Road, Bridge and Municipal Construction

1.03 DEFINITIONS
A. Welds: Welding terms and definitions are per ANSI/AWS A3.0. Welding symbols are per ANSI/AWS A2.4.
B. Structural Steel: Elements of structural-steel frame, as classified by AISC 303, that support design loads

C. Seismic Load Resisting System (SLRS): Assembly of Structural Steel elements that resist seismic loads. Members of SLRS are indicated in the Contract Drawings.

D. Seismic Demand-Critical Welds: Welds in the SLRS including:
   1. Complete penetration welds in beam-to-column connections, including welds to flanges, webs, and flange reinforcement, stiffener, and doubler plates.
   2. Complete penetration welds of column splices and of columns to base plates.
   3. Fillet welds connecting braced frame gusset plates to braces, beams, and columns.
   4. Other welds indicated as “Seismic Demand Critical” on the Contract Drawings.

E. Protected Zones: Area of a member in which limitations apply to fabrication and attachments. See Part 3 of this Section.

F. Lowest Anticipated Service Temperature: 0 degrees Fahrenheit, as required by ANSI/AWS D1.8/D1.8M

1.04 SUBMITTALS

A. Shop Drawings: In compliance with AWS A2.4 and AWS A3.0.

B. Transmit: Manufactured Products:
   1. Welding Electrode: Manufacturer’s certification of conformance
   2. High-Strength Bolts, Nuts, and Washers: Manufacturer’s mill certificates demonstrating conformance.
   4. Direct Tension Indicating Washers: Manufacturer’s mill certificates demonstrating conformance, if proposed for use.
   5. Tension Control Structural Bolt-Nut-Washer Assemblies: Manufacturer’s mill certificates demonstrating conformance, if proposed for use.

C. Transmit: Welder Qualifications: WABO certified welders. Transmit certified copies of qualification test records for each welder, welding operator, and tack welder to be employed in the work.
   1. Transmit welders' identification marks (ID) for each welder along with qualifications.

D. Transmit: Welding Procedures: Prior to commencement of welding, transmit the procedure to be used for qualifying welding procedures. For procedures other than those pre-qualified in accordance with AWS D1.1/D1.1M Structural Welding Code - Steel, submit a copy of procedure qualification test records in accordance with the qualification requirements of AWS D1.1/D1.1M; Section 4, Parts A and B.

E. Transmit: Inspector Qualifications:
   1. Welding Inspector per 1.05 Quality Assurance.
2. Personnel Performing Nondestructive Testing per 1.05 Quality Assurance.

F. Transmit: Welding Records and Data: For field welding, transmit descriptive data for field welding test results and equipment used.

G. Transmit: Mill Certificates: Retain mill certificates and certified copy of reports for all analyses and tests required by referenced AWS specifications.

H. Transmit: Inspection and Test Reports: Forward inspection and test results to the Resident Engineer immediately after results are available. Results shall state whether results are conforming or nonconforming.

1. Visual inspection reports
2. Nondestructive test reports as required by Article 2 of this specification

1.05 QUALITY ASSURANCE

A. Qualifications of Welders, Welding operators, and Tack welders: In accordance with AWS D1.1/D1.1M, Section 4, "Qualification".

B. Qualification of Welding Procedures: Prequalified or qualified in accordance with AWS D1.1/D1.1M, Section 4, "Qualification".

C. Qualifications of Welding Inspector: Contractor-employed AWS Certified Welding Inspector (CWI), certified in accordance with AWS QC1.

D. Qualification of Personnel Performing Nondestructive Testing (NDT):
   2. Only persons certified for NDT Level I and working under a NDT Level II person or persons certified for NDT Level II may perform nondestructive testing.

E. Weldability of Steel: For structural steel requiring impact test qualification, establish the weldability of the steel and the procedures for welding by qualification in accordance with AWS D1.1/D1.1M, Section 4, to match the notch toughness and weathering characteristics of the base metal.


1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle welding electrodes in conformance with ANSI/AWS D1.1/D1.1M

B. Deliver, store, and handle bolts, nuts, and washers in conformance with RCSC Specification.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Fasteners
   1. High Strength Bolts
a. Bolt: ASTM F3125 / F3125M  
b. Nuts: ASTM A563 heavy-hex  
c. Washers: ASTM F436  
d. Finish: Hot-dipped zinc coating per ASTM A153/A153M

2. Anchor Rods: ASTM F1554, Grade 55

3. Welded Shear Connectors and Welded Headed Studs: ASTM A108, grades 1010 through 1020, headed stud type, cold finished carbon steel, AWS D1.1/D1.1M, Type B.

2.02 MANUFACTURED PRODUCTS

A. Welding Electrodes for Structural Shapes, Plates, and Bars:
   1. Conform to ANSI/AWS A5 Series Standards, with a minimum tensile strength of 70 ksi. Provide coated rods or wire of size and classification number as recommended by the manufacturer for the positions and other conditions of actual use. Match filler metal requirements in conformance with ANSI/AWS D1.1/D1.1M.

B. High-Strength Bolts:
   1. Bolts: ASTM F3125 / F3125M  
   2. Nuts: ASTM A563 heavy hex  
   3. Washers  
      a. Plain: ASTM F436  
      b. Direct Tension Indicating: ASTM F959, Type 325 compressible-washer type  
   4. Finish  
      a. Hot-dipped zinc coat in conformance with ASTM A153/A153M, Class C.

C. Tension Control Structural Bolt-Nut-Washer Assemblies:
   1. Bolts: ASTM F1852, Type 1, heavy hex head splined ends  
   2. Nuts: ASTM A563 heavy hex  
   3. Washers: ASTM F436  

D. Mild Bolts: Provide mild bolts where noted A307
   1. Bolts: ASTM A307, Type A  
   2. Nuts: ASTM A563A hex  
   3. Washers: ASTM F844  
2.03 EQUIPMENT

A. Welding Rod/Electrodes for structural plate, shapes and bars.
   1. Conform to AWS A5 Series Standards.
   2. Use coated rods or wire of size and classification number as recommended by their manufacturers for the positions and other conditions of actual use. Match filler metal in conformance with AWS D1.1/D1.1M, Table 3.1 or 3.2 consistent with design requirements.

2.04 FABRICATION

A. Unless specifically noted as field-welded, welds may be shop or field welded at the Contractor’s option.

B. Welding of reinforcing steel for concrete: Conform to concrete reinforcing requirements as stated elsewhere in the Contract Documents.

C. Shop Welding
   1. Perform shop welding as indicated in accordance with ANSI/AWS D1.1/D1.1M, AWS D1.5M/D1.5, ANSI/AWS D1.6/D1.6M, AWS D1.8/D1.8M, and ANSI/AWS D1.3/D1.3M, as applicable to the work.
   2. Weld joints in conformance with approved AWS. Make ANSI/AWS D1.1/D1.1M available to welders and inspectors during fabrication.
   3. Provide complete joint penetration welds for groove welds indicated on the Contract Drawings unless noted otherwise. Select groove preparation in conformance with ANSI/AWS D1.1/D1.1M.
   4. Remove backing bars for complete joint penetration welds where indicated in the Contract Drawings or required for testing and inspection.
   5. Mark welder ID adjacent to completed weld using metal stamp, metal engraving, keel, paint stick, or other appropriate marking material.
   6. Weld stud shear connectors in conformance with stud manufacturer's printed instructions.
   7. Repairs: ANSI/AWS D1.1/D1.1M. Re-inspect or retest repaired or corrected welds as specified for the original weld.

D. Anchorage to concrete: As stated elsewhere in the Contract Documents

E. Shop Bolting
   1. Drive bolts accurately into holes without damaging the thread. Protect bolt heads from damage during driving. Place washers and all bolt heads and nuts. Rest bolt heads and nuts squarely against the washers.
   2. High-Strength Bolting
      b. Pretension bolts unless noted otherwise.
c. Prepare faying surfaces for joints indicated as Slip-Critical in conformance with Class C for galvanized items, and in conformance with Class A for non-galvanized items.

d. Snug-tight connections may be used in beam-to-beam connections only if specified on the plans or approved by an Engineer with the appropriate authority.

2.05 SHOP WELD QUALITY CONTROL

A. Shop Welding Procedures and Personnel: Verify the following prior to and during fabrication:

1. Welder qualifications and identifications.

2. Welding Procedures Specification (WPS) has been provided to and reviewed with each welder performing the Work.

3. Consumables meet WPS requirements.

4. Joint fit-up meets WPS requirements. Mark joint prior to welding.

5. Preheat and interpass temperatures and weld pass sequence meet WPS requirements.

B. Shop Welding Inspections and Testing

1. Visual Inspection: ANSI/AWS D1.1/D1.1M. Visually inspect 100 percent of welds, for both permanent and temporary Work.

2. Ultrasonic Testing: ANSI/AWS D1.1/D1.1M, and ASTM E164, as applicable. Ultrasonically test complete joint penetration groove welds as follows:

a. 10 percent with material thickness equal to or less than 3/4 inch.

b. 50 percent with material thickness greater than 3/4 inch and equal to or less than 1-1/2 inches.

c. 100 percent for material thickness greater than 1-1/2 inches.

3. Magnetic Particle Inspection: ASTM E709. Inspect complete and partial joint penetration groove welds and fillet welds as follows:

a. 20 percent of complete joint penetration groove welds of tee and corner joints.

b. 10 percent of partial joint penetration groove welds and fillet welds.

4. Liquid Penetrant Inspection: ASTM E165/E165M. Liquid penetrant inspection may be used for detecting discontinuities that are open to the surface.


6. Nondestructive Testing:


b. For Permanent and Temporary Work: in accordance with WSDOT Standard Specifications Section 6-03.3(25)A.
7. Quality of welds and standards of acceptance: In accordance with AWS D1.1/D1.1M, Sections 5, and 6, as applicable.

8. Test Results: Submit test result information to the Resident Engineer immediately after test results are available, stating the acceptance or rejection of fabricated components, so that repairs and re-inspection or testing may be performed as soon as possible.

9. Repairs: Repair unacceptable welds in accordance with AWS D1.1/D1.1M, Section 5.25. Re-inspect or retest repaired or corrected welds as specified for the original weld.

C. Shop Bolting Inspection and Testing

1. Torque Wrench Calibration
   b. Test the calibrating device for setting calibrated torque wrenches for accuracy using qualified personnel not more than 30 days prior to first use on the Work, and at intervals not more than six (6) months thereafter.
   c. If the Resident Engineer has reason to question the accuracy of the calibrating device, return it to the manufacturer for certification of accuracy.

D. Shop Inspections and Tests

1. Independent verification inspection and testing at the shop shall conform to requirements in Section 01 45 00 Quality Assurance / Quality Control.

2. All welds and bolted connections are subject to inspections and testing for conformance to requirements in Section 01 45 00 Quality Assurance / Quality Control.

PART 3 - EXECUTION

3.01 ERECTION

A. Field Welding and Field Welding Repairs: Perform field welding and field welding repairs as specified for shop welding and shop welding repairs.

B. Field Bolting: Perform field bolting as specified for shop bolting.

3.02 CONNECTIONS AT PROTECTED ZONES

A. Protected Zones are as indicated on the Contract Drawings.

B. Within protected zones, discontinuities created by fabrication or erection operations, such as tack welds, erection aids, air-arc gouging and thermal cutting shall be repaired as required by the Resident Engineer.

C. Welded shear studs and decking attachments that penetrate the beam flange shall not be placed on beam flanges within the Protected Zones. Decking arc spot welds as required to secure decking shall be permitted.
D. Welded, bolted, screwed or shot-in attachments for perimeter edge angles, exterior facades, partitions, duct work, piping or other construction shall not be placed within the Protected Zone.

3.03 FIELD QUALITY CONTROL

A. All quality control measures herein shall be in conformance to requirements in Section 01 45 00 Quality Assurance / Quality Control.

B. Field Welding Procedures and Personnel: Verify field welding procedures and personnel prior to and during field welding as specified for shop welding procedures and personnel.

C. Field Welding Inspection and Testing: Perform field welding inspection and testing as specified for shop welding inspection and testing.

D. Field Bolting Inspection and Testing: Perform field bolting inspection and testing as specified for shop bolting inspection and testing.

E. Verify all tests and inspections demonstrate conformance with the Contract Documents before loading structures, either temporary or permanent and submit results to the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing, fabricating, and erecting structural steel.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Institute of Steel Construction (AISC)
   a. AISC 360 Specification for Structural Steel Buildings
   b. AISC 341 Seismic Provisions for Structural Steel Buildings
   c. AISC 303 Code of Standard Practice for Steel Buildings and Bridges

2. ASTM International (ASTM)
   b. ASTM A36/A36M Standard Specification for Carbon Structural Steel
   c. ASTM A53/A53M Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   d. ASTM A108 Standard Specification for Steel Bars, Carbon and Alloy, Cold-Finished
   e. ASTM A252 Standard Specification for Welded and Seamless Steel Pipe Piles
   g. ASTM F3125 / F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi and 150 ksi Minimum Tensile Strength
   h. ASTM A500/A500M Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
   i. ASTM A563 Standard Specification for Carbon and Alloy Steel Nuts
   j. ASTM A572/A572M Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
   k. ASTM A992/A922M Standard Specification for Structural Steel Shapes
1. ASTM F436 / F436M Standard Specification for Hardened Steel Washers

m. ASTM F959 / F959M Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners

n. ASTM F1554 Standard Specification for Anchor Bolts, Steel, 36, 55, and 105-ksi Yield Strength

3. American Welding Society (AWS)
   a. ANSI/AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination
   b. ANSI/AWS D1.1/D1.1M Structural Welding Code - Steel
   c. AWS D1.8 Structural Welding Code – Seismic Supplement

4. Research Council on Structural Connections (RCSC)
   a. RSCS Specification for Structural Joints Using ASTM F3125 / F3125M Bolts

5. The Society for Protective Coatings (SSPC)
   a. SSPC SP 6 Commercial Blast Cleaning

6. Washington Department of Transportation (WSDOT)
   a. WSDOT Standard Specifications for Road, Bridge and Municipal Construction

7. American Association of State Highway and Transportation Officials (AASHTO)
   a. AASHTO LRFD Bridge Design Specifications

8. American Petroleum Institute (API)
   a. API Specification 5L

1.03 DEFINITIONS

A. Structural Steel: Elements of structural-steel frame, as classified by AISC 303, that support design loads.

B. Seismic Load Resisting System (SLRS): Assembly of Structural Steel elements that resists seismic loads. Members of SLRS are indicated in the Contract Drawings.

C. Demand-Critical Welds: Welds in the SLRS including:

1. Complete penetration welds in beam-to-column connections, including welds to flanges, webs, and flange reinforcement, stiffener, and doubler plates.

2. Complete penetration welds of column splices and of columns to base plates.

3. Fillet welds connecting braced frame gusset plates to braces, beams, and columns.

4. Other welds indicated as “Seismic Demand Critical” on the Contract Drawings.
D. Protected Zone: See Contract Drawings for members or parts of members defined as Protected Zones, and surface of braced frame diagonal member, its gusset plates and cover plates in which restrictions apply to fabrication and attachments. Protected zones are noted on the Contract Drawings.

1.04 SUBMITTALS

A. Shop Drawings:

1. Submit detailed shop drawings of structural steel work, including erection plans and piece drawings, showing member sizes, details of fabrication and construction, methods of assembly, field welding, spacing and locations of members, hardware, anchors, openings, weep holes and locations, and accessories, and erection sequence and details. Include procedures for heavy lifts and rigging.

2. Welding Procedures: Submit welding procedures and overall fabrication methods in conformance with AWS D1.1/D1.1M.

3. Include in shop drawings member identity, welding technique, cuts, copes, gussets, connections, holes, fasteners, camber, fabrication and erection tolerances, type of finish, paint system, weights of members, and critical clearances. Indicate locations of Protected Zones.

4. Indicate welds, both shop and field, using standard welding symbols of ANSI/AWS A2.4. Show the size, length, and type of each weld on drawings. Identify welds to the SLRS and Demand Critical Welds.

5. Indicate type, size, and length of bolts, distinguishing between shop and field bolts. Identify pretensioned and slip-critical high-strength bolted connections.

6. Verify all dimensions and coordinate with adjoining work.

7. Indicate individual welders' identification (ID) on Contract record documents.

8. All shop drawings shall be reviewed by and coordinated for handholes with the corresponding subcontractors.

B. Template Drawings and Placement Plans: As required for satisfactory placing of connections and anchorages.

C. Working Drawings and Method Statements:

1. Investigate stresses caused by the proposed erection procedure.

2. Submit the construction sequence for erection and disassembly of the shoring system. Indicate how sequence is coordinated with interim grading and drainage and the construction of the permanent structure.

3. Submit drawings sealed by a Professional Engineer. Show details of required temporary supports, staying, and bracing. Include descriptive data to illustrate the erection, transportation, and handling procedures, including sequence of erecting and transfer of loads if applicable.

4. Submit calculations sealed by a Professional Engineer supporting the drawings and other descriptive data.

5. Furnish setting diagrams, templates, and directions for the erection of structural framing, anchor bolts, bearing plates, and other embedded items.
D. Transmit: Product Data:
1. Transmit manufacturer’s product data for load-indicator washers (Compressible washer-type direction tension indicators), bolts and accessories.
2. Transmit data on coating system. Assure compatibility between steel shop primer and intermediate and finish high performance coatings. This submittal will not be considered complete and acceptable if either product is not compatible with each other.

E. Transmit: Certificates:
1. At completion of fabrication, the approved fabricator shall transmit a Certificate of Compliance and copy to the Building Official stating that the work was performed in accordance with the approved construction documents.

F. Transmit: Mill test reports of structural steel materials, showing:
1. Name, address and phone number of the steel manufacturer
2. Statement identifying the type of steel referenced on the mill certification (for example: carbon plate, ASTM A36/A36M/ASME SA36)
3. Statement that the steel was melted and rolled in the USA
4. Number of pieces represented by the mill certification (for example: 6 pieces, 12 feet by 12 feet by 6 inches)
5. Physical properties including; Heat Number, Yield Strength, Tensile Strength, Percentage of Elongation, Hardness (if applicable) and Bend Tests (if applicable)
6. Chemical Analysis as applicable for each type of steel and each heat number referenced on the mill certification including; Carbon, Manganese, Phosphorus, Sulfur, Silicon, Copper, Nickel, Vanadium, Columbium, Aluminum, Chromium, Molybdenum, and Cerium
7. Signature of the person that prepared the mill certificate

G. Transmit: Qualifications:
1. Fabricator: AISC certification demonstrating conformance, and current work history.
2. Erector: AISC certification demonstrating conformance, and current work history.
3. Professional Engineer: License number, and current work history.

H. Welding Records and Data: Refer to metal fastenings for the requirements as stated elsewhere in the Contract Documents.

1.05 QUALITY ASSURANCE

A. Fabricator:
1. Currently certified under the AISC Certification Program, Category BU
2. Minimum of five (5) years of experience with successfully completed structural steel work of similar complexity
B. Erector:
   1. Minimum of five (5) years of experience with successfully completed structural steel work of similar complexity

C. Professional Engineer: Licensed professional engineer currently registered in the State of Washington.

D. Certifications of Welders: Refer to 05 05 23 Metal Fastenings for the requirements.

E. Certifications of Welding Procedures: Refer to 05 05 23 Metal Fastenings for the requirements.

1.06 DELIVERY STORAGE AND HANDLING

A. Load, transport, unload, and store structural steel materials in such a manner that the metal is kept clean and free from injury. Store materials above ground on platforms, skids, or other supports, and cover and protect from corrosion.

B. Mark weight and piece (mark) number, corresponding to shop erection sequence drawing, on all members. Match-mark all shop pre-fitted members.

C. Ship small parts, such as bolts, nuts, washers, pins, fillers, clips, and small connecting plates and anchors, in boxes, crates, or barrels, plainly mark with an itemized description of the contents on the outside of each container.

D. Pack separately each length and diameter of bolt and each size of nut and washer.

E. Avoid bending, scraping, and overstressing the steelwork. Block with wood, or otherwise protect, projecting parts that may be bent or damaged.

PART 2 - PRODUCTS

2.01 STRUCTURAL STEEL SHAPES UNLESS NOTED OTHERWISE

A. Wide Flange Shapes: ASTM A992/A992M Gr. 50, AASHTO M270 Gr. 50

B. Channels: ASTM A36/A36M

C. Angles: ASTM A36/A36M

D. Plate:
   1. Unless noted otherwise: ASTM A36/A36M
   2. ASTM A572/A572M, Grade 50

E. Hollow Structural Sections
   1. Rectangular: ASTM A500 / A500M, Grade B, Fy = 46 ksi
   2. Round, diameter equal to or less than 20 inches: ASTM A500 / A500M, Grade B, Fy = 42 ksi

F. Pipe, diameter equal to or less than 12 inches: ASTM A53 / A53M, Grade B, Fy = 35 ksi.
2.02 MANUFACTURED PRODUCTS

A. Bolts: Refer to metal fastenings, materials as stated elsewhere in the Contract Documents.

B. Welding Electrodes: Conform to metal fastenings, materials, for the requirements as stated elsewhere in the Contract Documents.

C. Unheaded anchor rods: ASTM F1554, Grade 55 unless otherwise noted on structural drawings. Finish: Plain

D. Headed anchor rods: ASTM F1554, Grade 55 unless otherwise noted on structural drawings. Finish: Plain

E. Threaded Rods: ASTM A36/A36M

F. Shear connectors: ASTM A108, Grades 1015 through 1020, headed stud type, cold-finished carbon steel; AWS D1.1/D1.1M, Type B.

G. Fasteners: Conform to metal fastenings, materials, for the requirements as stated elsewhere in the Contract Documents.

2.03 FABRICATION

A. Protected Zones: Members and parts of members defined as Protected Zones in the Drawings, shall not have connections made into the protected zones and shall not be modified or damaged as indicated below. Protected Zones occur at braced frames and members or parts of members as indicated on the Drawings. Within the protected zones, the fabrication and erection shall prevent the following:

1. Discontinuities created by fabrication or erection operations, such as tack welds, erection aids, air-arc gouging and thermal cutting shall not be made.

2. Welded shear studs and decking attachments that penetrate the beam flange shall not be placed on beam flanges within the protected zone. Decking arc spot welds as required to secure decking shall be permitted.

3. Welded, bolted, screwed or shot-in attachments for perimeter edge angles, exterior facades, partitions, duct work, piping or other construction shall not be placed within the protected zones.

B. Conform to the applicable requirements of AISC 360.

C. Conform to metal fastenings, fabrication, for the requirements as stated elsewhere in the Contract Documents.

D. Prefabricate and preassemble steel members and metal fabrications in the factory or shop as far as practicable. Mark and match-mark materials for field assembly.

E. Form and fabricate the work to meet installation conditions. Include accessories to adequately secure the work in place. Be responsible for errors of fabrication and for correct fitting of structural members.

F. All electrical, system and mechanical handholes shall be centered on the centerline of the member webs. Holes shall not have sharp corners - all corners for handholes shall be rounded (radius of 2 times the web thickness).

G. Seal joined members exposed to weather by continuous welds. Grind exposed welds smooth.
H. Straighten rolled material, if necessary, before it is laid out for fabrication, in a manner conforming to the mill tolerances specified in ASTM A6/A6M, and by a process and in a manner which does injure the material. Sharp kinks and bends are cause for material rejection. Do not use heat shrunk low-alloy structural steel.

I. Perform shearing, flame cutting, and chipping carefully and accurately so as not to induce residual stress in the metal being cut. Hold the radii of re-entrant gas-cut fillets not less than 3/4 inch and as much larger as practicable. For cut edges exposed in the finished work, machine cut, shear, or flame cut, and grind flush in conformance with AISC 360. Maintain all working points.

J. Maintain all working points.

K. Fabricate joints which will be exposed to weather in a manner to exclude water or provide weep holes where water may accumulate. Provide 1/4 inch diameter weep holes (flame cut holes are prohibited) at the low points of all vertical and diagonal HSS, pipe and tube members; at the bottoms of all horizontal HSS, pipe and tube members (minimum 2 per members).

L. Fabricate bearing stiffeners and stiffeners intended as supports for concentrated loads as indicated. Mill or grind bearing surfaces of these stiffeners.

M. Bend load-carrying cold-rolled steel plates cold at right angles to the direction of rolling. Bend such that the radius of bend, measured to the concave face of the metal, is not less than indicated in the following table, in which T is the thickness of the plate.

<table>
<thead>
<tr>
<th>ANGLE THROUGH WHICH PLATE IS BENT</th>
<th>MINIMUM RADIUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>61 to 120 degrees</td>
<td>1.0 T</td>
</tr>
<tr>
<td>121 to 150 degrees</td>
<td>2.0 T</td>
</tr>
</tbody>
</table>

1. If a shorter radius is indicated, bend the plate hot. Before bending, round plate edges where bending occurs to a radius of 1/16 inch.

N. Bolt or weld connections as indicated on the Contract Drawings.

O. At Station Entrances, Systems Raceways, Interior Soffit Framing and any Structural Steel Framing within 20 feet of public walking surfaces, do not use screws or bolts wherever welding can be performed at connections. When bolts must be used at connections, countersink heads and draw up tight; nick threads to prevent loosening.

P. Unless specific visual acceptance criteria for Weld Show-Through are specified in the Contract Documents, the members or components shall be acceptable as produced. At Station Entrances, Systems Raceways, Interior Soffit Framing and any Structural Steel Framing within 20 feet of public walking surfaces, minimize Weld Show-Through where exposed to view through use of intermittent welds, selection of weld type (i.e., gas shield instead of arc), and heat dissipation techniques employed in the fabrication and assembly process.

Q. Visible welds at Station Entrances, Systems Raceways, Interior Soffit Framing and any Structural Steel Framing within 20 feet of public walking surfaces: All welds that are exposed to view at Station Entrances shall be ground flush and smooth and meet the requirements in AWS D1.1/D1.1M, also all groove and plug welds that are exposed to view shall not project more than 1/16 inch above the exposed surface and remove weld spatter at all surfaces exposed to view. In addition:

1. Make exposed joint butt tight, flush, and hairline. Ease exposed sheared edges to a radius of approximately 1/32 inch, unless otherwise indicated.
2. Form bent metal corners to smallest radius possible without causing grain separation or otherwise impairing work.

3. Seal continuous welds to close any open gaps.

4. Close all weld access holes at full penetration welds.

5. Unless otherwise indicated on the drawings, weld all shop connections.

6. Tack welds shall be ground smooth and holes shall be filled with weld metal, and smoothed by grinding or filing.

R. Drill or punch holes at right angles to the surface of the metal. Do not flame cut holes or enlarge holes by burning. Drill holes in base or bearing plates. Provide holes in members to permit connecting the work of other trades. Punch or drill holes at 1/16 inch larger than the diameter of the bolt.


T. For items bearing on concrete, provide steel bearing plates and anchors. Level base or bearing plates by means of adjustment nuts. Furnish templates, together with instructions for setting of anchors, anchor bolts, and bearing plates. Set anchors and related items properly in concrete during the progress of the work.

U. Fabricate metal bearing surfaces that contact preformed elastomeric bearing pads or grout flat to within 1/8-inch tolerance in 12 inches and to within 3/16 inch overall.

V. Include reinforcing angles, clip angles, plates, punched straps, brackets, and hangers as required to complete the work as indicated.

W. Provide drainage holes in structural components to prevent water accumulation.

X. Where finishing is required, complete the assembly, including welding of units, before start of finishing operations. Finish surfaces of members exposed in the final structure shall be free of markings, burrs, and other defects.

Y. Repair discontinuities within Protected Zones caused by fabrication operations such as tack welds, erection aids, air-arc gouging, and thermal cutting in conformance with AWS D1.8.

Z. Erection marks or other painted marks shall not be made on those surfaces of weathering steel members that are to be exposed in the completed structure. Unless otherwise specified in the Contract Documents, clean weathering steel members to meet the requirements of SSPC SP 6.

AA. At Station Entrances, Systems Raceways, Interior Soffit Framing and any Structural Steel Framing within 20 feet of public walking surfaces, stamped or raised manufacturer’s identification marks shall be filled, ground, or otherwise removed.

BB. Seams of hollow structural sections shall be acceptable as produced. Seams shall be oriented away from view or as directed in the Contract Documents.

CC. Welded Headed Stud shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of heads stud shear connectors according to AWS D1.1/D1.1M and manufacturer’s written instructions.
2.04 FINISHES
   A. Refer to contract documents for finish types and Section 05 05 13 and 09 96 00 for requirements.

2.05 WELDING
   A. Shop Welding and Shop Welding Repairs: Refer to Section 05 05 23 for welding requirements.

2.06 BOLTING
   A. Shop Bolting: Refer to Section 05 05 23 for shop bolting requirements.

2.07 SOURCE QUALITY CONTROL
   A. Fabricator's Facility
      1. Select a Fabricator certified by AISC. Submit certification in accordance with Article 1.04 herein.
      2. Provide the Resident Engineer access to inspect the AISC-Certified Fabricator's shop or facility before the start of fabrication work. Notify the Resident Engineer in writing at least 10 days before the scheduled start of fabrication work.

   B. Calibration of Torque Wrenches:
      1. Check the calibrating device for setting calibrated torque wrenches for accuracy using qualified personnel not more than 30 days prior to its first use on the work, and at intervals not more than 6 months thereafter.
      2. Provide copies of calibration records to the Resident Engineer.

   C. Correct deficiencies in work that test reports and inspections indicate non-conformance with the contract documents.

   D. In addition to visual inspection, shop-welded shear connectors will be tested and inspected according to requirements in AWS D1.1/D1.1M for stud welding.

PART 3 - EXECUTION

3.01 ERECTION AND INSTALLATION
   A. Protected Zones: Members and parts of members defined as Protected Zones in the Drawings, shall not have connections made into the protected zones and shall not be modified or damaged as indicated below. Protected Zones occur at braced frames, members or parts of members as indicated on the Drawings. Within the protected zones, the fabrication and erection shall prevent the following:
      1. Discontinuities created by fabrication or erection operations, such as tack welds, erection aids, air-arc gouging and thermal cutting shall not be made.
      2. Welded shear studs and decking attachments that penetrate the beam flange shall not be placed on beam flanges within the protected zone. Decking arc spot welds as required to secure decking shall be permitted.
3. Welded, bolted, screwed or shot-in attachments for perimeter edge angles, exterior facades, partitions, duct work, piping or other construction shall not be placed within the protected zones.

B. Reference Standards: Erect and install structural steel in conformance with the applicable requirements of AISC 360. Hold a readiness review meeting with the parties involved with the steel erection including the Resident Engineer after shop drawings and erection plans are approved.

C. Special Care: Use special care in unloading, handling, and erecting the structural steel materials to avoid marking or distorting the structural steel. Care shall also be taken to avoid damage to any shop paint. If temporary braces or erection clips are used, care shall be taken to avoid the creation of unsightly surfaces upon removal. Plan and execute all operations in such a manner that the close fit and neat appearance of the structure will not be impaired.

D. Prior to erection, verify elevations of concrete and masonry bearing surfaces and locations of anchor rods, bearing plates, and other embedments, with steel erector present, for compliance with requirements. Proceed with installation only after unsatisfactory conditions have been corrected.

E. Lines and Levels: Install structural steel accurately at established lines and levels. Install steel plumb and level before bolting is commenced. Install in accordance with accepted shop drawings and actual conditions, true and horizontal or perpendicular as the case may be, level and square, with angles and edges parallel with related lines of the structure.

F. Temporary Bracing: Provide temporary bracing as required and keep in position until final completion. Brace and carefully handle shop fabricated items subject to damage to prevent distortions or other damage. Properly brace all items installed before concrete is placed to prevent distortion by pressure of concrete. Watch and maintain bracing during concreting operations.

G. Bases and Bearing Plates:

1. Clean concrete and masonry bearing surfaces of bond-reducing materials, and roughen surfaces prior to setting base and bearing plates. Clean bottom surfaces of base and bearing plates. Promptly pack grout solidly between bearing surfaces and base or bearing plates so no voids remain.

2. Set base and bearing plates accurately using a high-strength, non-shrink grouting mortar in accordance with non-shrink grouting, installation, as stated elsewhere in the Contract Documents.

3. Support bases and plates that require grouting at the correct level by means of adjustment nuts on anchor bolts.

H. Erection and Assembly: Do not place dissimilar metals in contact with each other. After erection and field assembly, align the various members forming parts of the completed structure and adjust accurately before fastening. Conform to the applicable tolerance requirements of AISC 303.

I. Elevator hoistway structural steel support framing connection to the concrete platform structure shall be erected with a sufficient time after Station fill is placed and compacted. Consult the project geotechnical engineer for the required time for consolidation.

J. Splice members only where indicated. Fasten splices of compression members after bringing abutting surfaces completely into contact.
K. Do not use thermal cutting during erection unless approved by the Resident Engineer. Finish thermally cut sections within smoothness limits in AWS D1.1/D1.1M. Cutting will be permitted only on secondary members, which are not under stress, as acceptable to the Resident Engineer.

L. Drift Pins: Drift pins may be used only to bring together several parts or components. Do not use fit-up bolts and drift pins to bring out-of-tolerance fabricated members and components into alignment. Do not use drift pins with such force as to distort or damage the material.

M. Erection Connections:
   1. Place holes, plates, or other attachments required by the erector so as not to interfere with or cause any other detrimental effect to structural members or connections.
   2. Remove erection bolts and attachments not shown on the Contract Drawings.
   3. Fill holes not shown on the Contract Drawings with plug welds and grind smooth at exposed surfaces.

N. Welded Headed Stud Shear Connectors: Prepare steel surfaces as recommended by manufacturer of shear connectors. Use automatic end welding of heads stud shear connectors according to AWS D1.1/D1.1M and manufacturer’s written instructions.

3.02 WELDING
A. Field Welding and Field Welding Repairs: Refer to Section 05 05 23 Metal Fastenings for welding requirements as stated elsewhere in the Contract Documents.

3.03 BOLTING
A. Field Bolting: Refer to Section 05 05 23 Metal Fastenings for bolting requirements as stated elsewhere in the Contract Documents.
B. High-Strength Bolting: Assemble joints in accordance with AISC Specifications for Structural Joints Using F3125/F3125M Bolts.

3.04 PROTECTION AND REPAIR
A. Corrective Measures
   1. Report any errors in location or inaccuracies in setting anchor bolts, base plates, bearing plates, or other items of attachment or support for steel work to the Resident Engineer immediately. Correct as directed by the Resident Engineer.
   2. Report any fit-up errors due to misfabrication to the Resident Engineer immediately, along with a proposed corrective measure. Do not proceed with corrective measures until approved by the Resident Engineer.
   3. Correct bolted or welded connections, joints, or fastenings considered defective by the Resident Engineer as approved by the Resident Engineer.
B. Use fire-retardant blankets to completely contain arcs and spatter associated with welding.
C. Protected Zones:
   1. Keep Protected Zones free of attachments such as welds, bolts, screwed or shot-in fasteners, limiting connection of perimeter edge angles, light gauge framing, partitions, duct work, piping, and other construction.
   2. Repair Protected Zones in conformance with AWS D1.8

3.05 FIELD QUALITY CONTROL

A. Field Welding Procedures and Personnel: Refer to metal fastenings, field quality control, for the requirements as stated elsewhere in the Contract Documents.

B. Field Welding and Weld Repair Testing and Inspection: Refer to metal fastenings, field quality control, for the requirements as stated elsewhere in the Contract Documents.

C. Field Bolting Testing and Inspection: Refer to metal fastenings, field quality control, for the requirements as stated elsewhere in the Contract Documents.

D. Field-assembled and installed high-strength bolting will be inspected by the directions of the Resident Engineer. The independent laboratory shall torque-test bolts in accordance with RCSC Specification for Structural Joints using F3125/F3125M Bolts.

E. Perform visual inspection and non-destructive testing (NDT) of welds in accordance with WSDOT Standard Specifications Section 6-03.3.

F. Correct deficiencies in work that test reports and inspections indicate non-conformance with contract documents.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for furnishing and installing metal roof deck, composite metal floor deck, and accessories as indicated.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
1. ASTM International (ASTM)
   a. ASTM A653/A653M Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM A780/A780M Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
   c. ASTM A924 Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
2. American Welding Society (AWS)
   AWS D1.3 Structural Welding Code – Sheet Steel
3. Steel Deck Institute (SDI)
   a. SDI Publication No. 31 Design Manual for Composite Decks, Form Decks, and Roof Decks

1.03 SUBMITTALS
A. Shop Drawings: Submit shop drawings showing:
   1. Dimensioned deck layout noting deck type, profile, and gage.
   2. Locations of and details for deck supports, laps, edges, and openings.
   3. Locations of and details for deck attachments.
   4. Locations of and details for deck accessories.
B. Transmit: Manufacturer’s Product Data:
   1. Metal Deck
      a. Profiles, properties, load and shear capacities of each type, profile, and gage used.
      b. Accessories.
c. Manufacturer's written instructions for storage, handling, and application.

2. Galvanizing Repair Compound
   a. Manufacturer's written instructions for storage, handling, and application.

C. Transmit: Field Quality Control test and inspection reports.


1.04 QUALITY ASSURANCE

A. Qualifications of Welders and Welding Procedures: Conform to metal fastenings as stated elsewhere in the Contract Documents.

B. AISI Specifications: Comply with calculated structural characteristics of steel deck according to AISI's "North American Specification for the Design of Cold-Formed Steel Structural Members."

1.05 DELIVERY STORAGE AND HANDLING

A. Store and handle products in conformance with manufacturer’s written directions.

PART 2 - PRODUCTS

2.01 PERFORMANCE REQUIREMENTS

A. Minimum deck gages are shown on the Drawings and are based on 2-span, unshored conditions. Heavier deck gages may be required for conditions other than these, depending on manufacturer’s layout and contractor’s layout. Deck supplier shall verify deck gages and capacities based on actual deck layout and span condition. Deviations in deck gages from those shown shall be submitted to the Resident Engineer, along with a valid ICC-ES/IAPMO-ES report for approval, prior to shop detailing.

B. In lieu of increasing deck gages, deck shoring may be used at Contractor’s option if acceptable to the Resident Engineer.

2.02 MANUFACTURERS

A. Metal Roof and Composite Floor Deck
   1. ASC Steel Deck; Product
   2. Verco Manufacturing Co.
   3. United Steel Deck, Inc.
   4. Wheeling Corrugating Co
   5. Epic Metals Corporation

2.03 MATERIALS

A. Metal Roof Deck
   1. Fabricate panels without top-flange stiffening grooves in conformance with SDI Publication No. 31.
2. Sheet Steel: ASTM A653/A653M, Structural Steel, Grade 33. Galvanizing to conform to ASTM A924, G90 zinc coating where deck is left permanently exposed. Galvanizing to conform to ASTM A924, G60 elsewhere.

3. Deck Type: profile, type, and gage as indicated in the Contract Documents.

B. Composite Metal Floor Deck:

1. Fabricate panels with integrally embossed or raised pattern ribs and interlocking side laps in conformance with SDI Publication No. 31.

2. Sheet Steel: ASTM A653/A653M, Structural Steel, Grade 33. Galvanizing to conform to ASTM A924, G90 zinc coating where deck is left permanently exposed. Galvanizing to conform to ASTM A924, G60 elsewhere.

3. Deck Type: profile, type, and gage as indicated.

C. Accessories:

1. Provide closures and flashings as indicated or required for complete and finished installation and as required to prevent leakage of concrete.

2. Side-Lap Fasteners: Corrosion-resistant, hexagonal washer head; self-drilling, carbon steel screws, No. 10 minimum diameter.

3. Provide cover caps for covering abutting ends where required.

4. Provide accessories and flashings of the same material as the deck and no lighter than 22-gage. Use the deck manufacturer's standard type, galvanized accessories as follows:
   a. Adjusting plates or segments of deck units in locations too narrow to accommodate full-size units.
   b. End closures to close the open ends at openings through the roof, where units terminate at exterior walls, and other locations where required.
   c. Sump pans at drains as indicated, fabricated from metal not lighter than 14 gage. For drains, cut holes in the field, and repair and touch up coating as stated elsewhere in the Contract Documents.

D. Welding Electrodes: Conform to metal fastenings as stated elsewhere in the Contract Documents.

E. Welded Headed Studs: Conform to anchorage to concrete as stated elsewhere in the Contract Documents.

F. Galvanizing Repair Compound: ASTM A780/A780M

2.04 FABRICATION

A. Metal Deck And Associated Metal Fabrications: SDI Publication No. 31.

B. Welding and Welded Connections: Conform to metal fastenings as stated elsewhere in the Contract Documents.

C. Prefabricate and preassemble in the shop as far as practicable.
2.05 SOURCE QUALITY CONTROL

A. Testing and Inspection:
   1. Materials, fabrications, and welding are subject to inspections in the shop. Perform testing using an approved independent testing laboratory.
   2. Weld Inspection: Conform to metal fastenings as stated elsewhere in the Contract Documents.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install deck panels and accessories according to applicable specifications and commentary in SDI Publication No. 31, manufacturer’s written instructions, and requirements in this Section.

B. Provide deck and accessories in conformance with the approved Shop Drawings.

C. Fasten deck panels to steel supporting members by arc spot (puddle) welds of the surface diameter indicated or arc seam welds with an equal perimeter that is not less than 1-1/2 inches long, and as follows:
   1. Weld Diameter: 1/2 inch, effective.
   2. Weld Pattern:
      a. Roof Deck: As indicated on Contract Drawings
      b. Floor Deck: As indicated on Contract Drawings

D. Locate deck bundles to prevent overloading of supporting members

E. Side-Lap and Perimeter Edge Fastening: Fasten side laps and perimeter edges of panels between supports, at intervals not exceeding the lesser of 1/2 of the span or 12 inches, and as follows:
   1. Mechanically fasten with self-drilling, No. 10 diameter or larger, carbon-steel screws
   2. Mechanically clinch or button punch

F. End Bearing: Install deck ends over supporting frame with a minimum end bearing of 2 inches, with end joints butted.

G. Ends of sheets shall be lapped a minimum of 2 inches over the support.

H. Position roof drain pans with flange bearing on top surface of deck. Fusion weld at each deck flute.
   1. Install reinforcing channels or zees in ribs to span between supports and weld.

I. Floor-Deck Closures: Weld steel sheet column closures and Z-closures to deck, according to SDI Publication No. 31 recommendations, to provide tight-fitting closures at open ends of ribs and sides of deck.
3.02 WELDING

A. Weld deck to supports in conformance with the approved Shop Drawings.

B. Procedures: Conform to metal fastenings welding requirements as stated elsewhere in the Contract Documents.

3.03 GALVANIZING REPAIR

A. Repair galvanized surfaces damaged from welding, handling, or installation immediately after installation. See shop applied coatings for metal as stated elsewhere in the Contract Documents including ASTM A780 / A780M.

B. Apply galvanizing repair compound in conformance with manufacturer’s written instructions.

C. Complete all galvanizing repair before concrete is placed.

3.04 FIELD QUALITY CONTROL

A. Inspect field welds and shear studs in conformance with metal fastenings as stated elsewhere in the Contract Documents.

END OF SECTION
SECTION 05 40 00
COLD-FORMED METAL FRAMING

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for cold-formed metal framing.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.

1. American Iron and Steel Institute (AISI)
   a. AISI S100 North American Specification for the Design of Cold-Formed Steel Structural Members

2. ASTM International (ASTM)
   a. ASTM A153/A153M Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   b. ASTM A653/A653M Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   c. ASTM C 645 - Standard Specification for Nonstructural Steel Framing Members
   d. ASTM C955 Standard Specification for Cold-Formed Steel Structural Framing Members
   e. ASTM C1007 Standard Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories

3. American Welding Society (AWS)
   a. AWS D1.1/D1.1M Structural Welding Code – Steel

4. The Society for Protective Coatings (SSPC)
   a. SSPC Paint 20 Zinc-Rich Coating Type I – Inorganic and Type II - Organic

1.03 SUBMITTALS
A. Transmit: Product Data:
   1. Data on standard framing members; describe materials and finish, product criteria, limitations and span tables.
   2. Manufacturer's data on factory-made framing connectors, showing compliance with requirements.
B. Shop Drawings: Indicate component details, framed openings, bearing, anchorage, loading, welds, and type and location of fasteners, and accessories or items required of related work.

1. Indicate framing layout.
2. Describe method for securing studs to tracks and for bolted framing connections.
3. Provide design Professional Engineer's stamp on shop drawings.

C. Design calculations stamped by a Professional Engineer.

D. Transmit: Certifications:

1. Welders and welding procedures: Submit certifications conforming to metal fastenings as stated elsewhere in the Contract Documents.

E. Transmit: Manufacturer's Installation Instructions: Indicate special procedures, conditions requiring special attention, and any other instructions.

1.04 QUALITY ASSURANCE

A. Designer Qualifications: A Professional Structural Engineer experienced in design of this Work and licensed in the State of Washington.

B. Calculate structural properties of framing members in accordance with requirements of AISI S100.

C. Manufacturer Qualifications: Company specializing in manufacturing the types of products specified in this section, and with minimum three (3) years of documented experience.

D. Installer Qualifications: Company specializing in performing the work of this section with minimum five (5) years of experience.

E. Design structural elements under direct supervision of a Professional Structural Engineer experienced in design of this Work and licensed in the State of Washington.

F. Welding: Conform to metal fastenings as stated elsewhere in the Contract Documents for requirements for welders, welding procedures, and inspections.

G. The work of this section is subject to testing and inspection conforming to quality assurance/quality control as stated elsewhere in the Contract Documents.

H. Regulatory Requirements:

1. Framing system shall meet the requirements of the local authority having jurisdiction Building Code.

2. Furnish all calculations, engineer's stamps, drawings, and other items required by the local authority having jurisdiction to obtain approval of the installation.

1.05 PROJECT CONDITIONS

A. Verify that field measurements are as indicated on the Contract Drawings.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Framing System
   1. Provide primary and secondary framing members, bridging, bracing, plates, gussets, clips, fittings, reinforcement, and fastenings as required to provide a complete framing system.

B. Framing Materials
   1. Studs and Track: ASTM C955; studs formed to channel, "C", or "Sigma" shape with punched web; U-shaped track in matching nominal width and compatible height.
      a. Gage and depth: As required to meet specified requirements in the contract drawings.
      b. Galvanized in accordance with ASTM A653/A653M G90/Z275 coating.
      c. Vertical Deflection Track; As required to accommodate structural member deflection. Refer to deflection limit specified in the project design requirement.

C. Fasteners
   1. Self-Drilling, Self-Tapping Screws, Bolts, Nuts and Washers: Hot-dip galvanized in accordance with ASTM A153/A153M.
   2. Anchorage Devices: Powder actuated fasteners approved by Resident Engineer. Submit each type and size proposed for approval.
   3. Welding: In conformance with AWS D1.1/D1.1M.

2.02 ACCESSORIES

A. Bracing, Furring, Bridging: Formed sheet steel, thickness determined for conditions encountered; finish to match framing components.

B. Plates, Gussets, Clips: Formed sheet steel, thickness determined for conditions encountered; finish to match framing components.

C. Touch-Up Primer for Galvanized Surfaces: SSPC Paint 20, Type I - Inorganic, complying with VOC limitations of the US Environmental Protection Agency.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that substrate surfaces are ready to receive work.

3.02 INSTALLATION

A. Fasteners at Protected Zones
   1. Do not fasten to Protected Zones of steel braced frames in conformance with metal fastenings as stated elsewhere in the Contract Documents.
B. Stud Framing
1. Install components in accordance with manufacturers' instructions and ASTM C1007 requirements.
2. Place studs at 16 inches on center; not more than 2 inches from abutting walls and at each side of openings. Connect studs to tracks using clip and tie method.
3. Construct corners using minimum of three studs. Install double studs at wall openings and door and window jambs.
4. Install studs full length in one piece. Splicing of studs is not permitted.
5. Install load bearing studs, brace, and reinforce to develop full strength and achieve design requirements.
7. Install intermediate studs above and below openings to align with wall stud spacing.
8. Provide deflection allowance in stud track, directly below horizontal building framing at non-load bearing framing.
9. Attach cross studs to studs for attachment of fixtures anchored to walls.
10. Install framing between studs for attachment of mechanical and electrical items, and to prevent stud rotation.
11. Touch-up field welds and damaged galvanized surfaces with primer.

C. Soffit Joists
1. Install framing components in accordance with manufacturer's instructions.
3. Place soffit joists at 16 inches on-centers; not more than 2 inches from abutting walls. Connect joists to supports using fastener method.

D. Escalator Shrouds
1. Install shroud support components in accordance with manufacturers' recommendations and ASTM C1007 requirements.
2. Place components at not more than 16 inches on center; not more than 2 inches from escalator assembly and at each side of openings. Connect studs to furring tracks using clip and tie method or other method as approved by Resident Engineer.
3. Coordinate with escalator assembly design documents and field conditions as necessary.
4. Install cross-framing between framing studs for attachment of mechanical and electrical or other items, and to prevent stud rotation.

3.03 FIELD QUALITY CONTROL
A. Erection Tolerances
1. Maximum Variation from True Position: 1/4 inch.
2. Maximum Variation of all Members from Plumb: 1/8 inch in 10 feet.
3. Maximum Variation of all Members from Level: 1/8 inch in 10 feet.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for final engineering (delegated design), furnishing and installing continuous slot, bolted metal framing channels and all associated fittings and hardware.

1. Support framing for miscellaneous items such as (including but not limited to):
   a. Trapeze type supports for cable tray, conduit, pipe and other similar systems.
   b. Bolted metal framing as a surface metal raceway.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Iron and Steel Institute (AISI)
   a. AISI S100 North American Specification for the Design of Cold-Formed Steel Structural Members.

2. ASTM International (ASTM)
   a. ASTM A307 Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60000 psi Tensile Strength
   b. ASTM A563 Standard Specification for Carbon and Alloy Steel Nuts
   c. ASTM A653/A653M Standard Specifications for Steel Sheet, Zinc-Coated Galvanized or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   d. ASTM A1008/A1008M Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, solution Hardened, and Bake Hardenable
   e. ASTM B633 Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
   f. ASTM E488 Standard Test Methods for Strength of Anchors in Concrete Elements
   g. ASTM F1941/F1941M Standard Specification for Electrodeposited Coatings on Mechanical Fasteners

3. Metal Framing Manufacturers Association (MFMA)
   a. MFMA-4 Metal Framing Standards Publication
b. MFMA-103 Guidelines for the Use of Metal Framing

4. The Society for Protective Coatings (SSPC)
   a. SSPC SP 6 Commercial Blast Cleaning

5. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code, Chapter 3, Article 386 “Surface Metal Raceways” and Article 388 “Surface Nonmetallic Raceways”

1.03 SUBMITTALS
   A. Transmit: Product Data of strut members including, but not limited to, types, materials, finishes, gauge thickness, and hole patterns. For each different strut cross-section, submit cross sectional properties including Section Modulus (S) and Moment of Inertia (I).
   B. Shop Drawings: Submit drawings of strut and accessories including fasteners, clamps, brackets, hanger rods, and fittings stamped by a Structural Engineer licensed in the State of Washington.
   C. Calculations: Submit calculations stamped by a professional structural engineer licensed in the State of Washington. Provide calculations for struts and accessories demonstrating adequacy to support imposed loads. At a minimum, include the following:
      1. Design Criteria
      2. Selection of framing members, fittings and accessories
      3. Stress and deflection analysis
      4. Reactions and imposed loads transmitted to primary structure

1.04 QUALITY ASSURANCE
   A. Manufacturers: Firms regularly engaged in the manufacture of bolted metal framing of the types required, whose products have been in satisfactory use in similar service for not less than five (5) years.
   B. MFMA Compliance: Comply with the latest revision of MFMA Publication No. MFMA-4.
   C. NEC Compliance: Comply with the latest revision NFPA 70 – Articles 386 and 388.
   D. Bolted framing channels and fittings shall have the manufacturer’s name, part number, and material heat code identification number stamped in the part itself for identification. Material certification sheets and test reports shall be made available by the manufacturer upon request.
   E. Pre-Installation Conference: Prior to installation, conduct Readiness Review Meeting as defined in 01 45 10 Quality Assurance / Quality Control.

1.05 DELIVERY STORAGE AND HANDLING
   A. Deliver strut systems and components carefully to avoid breakage, denting, and scoring finishes. Do not install damaged equipment.
   B. Store strut systems and components in original cartons and in clean dry space; protect from weather and construction traffic.
PART 2 - PRODUCTS

2.01 METAL STRUT FRAMING SYSTEM DELEGATED DESIGN REQUIREMENTS

A. Meet the following criteria:

1. Local authorities having jurisdiction Building Code
2. American Iron and Steel Institute, AISI S100
3. Manufacturer’s published design criteria
4. For the strut system at the ceiling of the station platform, design the system to support the following loads:
   a. Gravity Loads: Strut system self-weight, plus the greater of the following:
      1) Uniform load of 10 pounds per square foot.
      2) Uniform load of 5 pounds per square foot, plus a concentrated load of 500 pounds located to produce the maximum stress in the element being designed.
      3) Actual weights of supported elements.
   b. Seismic loads: Generated by the mass of the system self-weight plus the actual weights of the supported elements in accordance with IBC.
   c. Wind Loads; Wind pressure on the framing and components supported by the framing in accordance with IBC.
5. For Metal Strut Framing Systems used for locations other than at the station platform ceiling, as indicated on the drawings, design the systems to support the following loads:
   a. Gravity Loads: Strut system self-weight, plus the greater of the following:
      1) A concentrated load of 250 pounds located to produce the maximum stress in the element being designed.
      2) Actual weights of supported elements.
   b. Seismic loads: Generated by the mass of the system self-weight plus the actual weights of the supported elements in accordance with IBC.
   c. Wind Loads; Wind pressure on the framing and components supported by the framing in accordance with IBC.

2.02 ACCEPTABLE MANUFACTURERS

A. Manufacturer: Subject to compliance with these specifications, strut systems to be installed shall be as manufactured by

1. Cooper B-Line, Inc.
2. Flex-Strut, Inc.
3. Powerstrut Corp.
4. Thomas & Betts Corp
5. Unistrut Division of Tyco, Inc.
6. Unitron Products, Inc.

2.03 STRUT CHANNELS AND COMPONENTS

A. Slotted Channel Framing: 1-5/8 inch wide cold-formed metal channels with continuous slot complying with MFMA Publication No. MFMA-4.

B. Material: Steel complying with ASTM A1008/A1008M, commercial steel, Type B; 0.0677-inch minimum thickness.

2.04 FASTENERS

A. Steel Bolts and Nuts: As stated elsewhere in the Contract Documents.

B. Expansion Adhesive Anchors: Anchor bolt assembly with capability to sustain, without failure, a load equal to six times the load imposed when installed in unit masonry and four times the load imposed when installed in concrete, as determined by testing as stated elsewhere in the Contract Documents.


2.05 FINISH

A. Preparation:

1. Prepare uncoated ferrous-metal surfaces to comply with SSPC SP 6.

2. Treat prepared metal with iron-phosphate pretreatment, rinse, and seal surfaces.

B. Finish all components except fasteners with flat black coating; manufacturer’s option of the following:

1. For all channels and components other than concrete inserts: Apply epoxy primer and topcoats to surfaces. Apply at spreading rates recommended by coating manufacturer. See painting and coating requirements as stated elsewhere in the Contract Documents.

2. For concrete inserts: Pre-galvanized zinc complying with ASTM A653/A653M

2.06 FABRICATION, GENERAL

A. Cut, drill, and punch metals cleanly and accurately. Remove burrs and ease edges to a radius of approximately 1/32 inch, unless otherwise indicated. Remove sharp or rough areas on exposed surfaces.

B. Form exposed connections with hairline joints, flush and smooth, using concealed fasteners where possible. Where exposed fasteners are required, use Phillips flat-head (countersunk) screws or bolts, unless otherwise indicated. Locate joints where least conspicuous.

C. Provide for anchorage of type indicated; coordinate with supporting structure. Space anchoring devices to secure metal fabrications rigidly in place and to support indicated loads.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Cutting, Fitting, and Placement: Perform cutting, drilling, and fitting required for installing metal fabrications. Set metal fabrications accurately in location, alignment, and elevation; with edges and surfaces level, plumb, true, and free of rack; and measured from established lines and levels.

B. Fastening to In-Place Construction: Provide anchorage devices and fasteners where metal fabrications are required to be fastened to in-place construction. Provide threaded fasteners for use with concrete and masonry inserts, toggle bolts, through bolts, lag bolts, wood screws, and other connectors.

C. Install framing and supports to comply with requirements of items being supported, including manufacturers’ written instructions and requirements indicated on Shop Drawings.

D. Install strut in accordance with MFMA Publication No. MFMA-103; in accordance with equipment manufacturer's recommendations, and with recognized industry practices.

E. Tighten nuts and bolts to the following values:

<table>
<thead>
<tr>
<th>Bolt Size</th>
<th>Torque (ft-lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 - 20</td>
<td>6</td>
</tr>
<tr>
<td>5/16 - 18</td>
<td>11</td>
</tr>
<tr>
<td>3/8 - 16</td>
<td>19</td>
</tr>
<tr>
<td>1/2 - 13</td>
<td>50</td>
</tr>
</tbody>
</table>

F. Electrical grounding required for metal strut framing located within 15-foot radius of centerline of track. Conform to grounding and bonding for electrical systems installation requirements as stated elsewhere in the Contract Documents.

3.02 FINISH REPAIR

A. Clean and touch up drilled holes, cuts, and minor abrasions in finishes with air dried coating that matches color and gloss of, and is compatible with the factory-applied finish coating as recommended by the manufacturer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies requirements for barrier cable systems in parking structures.

1.02 REFERENCES

A. Post-Tensioning Institute (PTI)

1. Technical Note 14, Design of Prestressed Barrier Cable Systems.
3. PTI M10.4 Specification for Seven Wire Steel Strand Barrier Cable Applications.

B. American Society for Testing and Materials (ASTM)

1. ASTM A416 Standard Specification for Low-Relaxation, seven-Wire Steel Strand for Prestressed Concrete.
2. ASTM A475 Standard Specification for Zinc-Coated Steel Wire Strand.

C. International Code Council (ICC)


D. American Society of Civil Engineers (ASCE) / Structural Engineering Institute (SEI)


1.03 DESIGN

The barrier cable system shall be compliant with the International Building Code and meet the following requirements:

A. Automobile/Pedestrian

1. Barrier cable systems shall be designed for vehicular and pedestrian design loads per ASCE 7. Strength verification of all the system components (cable, anchoring, hardware, posts, brackets, and structure members they attach to) shall be verified with a 1.6 load factor.

2. The system shall be a minimum of 42 in. in height and be constructed such that a 4 in. diameter sphere shall not pass through any opening up to a height of 34 in. Above 34 in., an 8 in. diameter sphere shall not pass through the openings.

3. Deflections shall be such that the top rail minimum elevation of 42” and cable spacing (4” maximum up to 34” of the floor than 8” maximum from there to 42” wherever a 30” or greater fall risk may occur) shall be guaranteed.
B. Design shall conform to Post-Tensioning Institute Technical Note 14, Design of Prestressed Barrier Cable Systems.

C. The barrier cable system, including all the system’s fabricated steel components and anchoring to the structural members shall be designed, fabricated, and installed by a single specialty company which qualification in compliance with paragraph 3.01 hereafter.

D. Intermediate through-posts and/or cable spacers shall be evaluated and provided to ensure that when collision occurs, all cables can act in unison without excessive vertical deflection.

E. If barrier cables run through an expansion joint, consideration shall be given to the restraining effects.

1.04 DEFINITIONS

A. Adjustable Anchorage: Device used to connect a barrier cable to its support that has a feature which allows for adjustment of the length and tension of the cable.

B. Anchorages: A mechanical device comprising all components required to anchor the prestressing steel and permanently transfer the post-tensioning force from the prestressing steel to the structure.

C. Barrel Anchor: A cylindrical metal device housing the wedges and normally used with a bearing plate to transfer the prestressing force to the concrete.

D. Barrier Cable System: Prestressing steel strands with anchorages erected along the perimeter of a structure and at open edges of ramps to restrain automobiles and pedestrians.

E. Barrier Strand: Seven-wire prestressing steel strand used in barrier cable systems.

F. Back-stressing: A stressing procedure that ensures that the wedges are properly seated into the anchor at a given location on the tendon.

G. Bearing Plate: A plate which bears directly against the concrete and is part of an overall anchorage system.

H. Cable: A term used by some to denote a prestressing strand or a single-strand tendon.

I. Casting: See anchorage.

J. Cast-in Anchor: An anchor that is Cast inside the concrete and recessed from the edge to give the required cover for corrosion and fire protection.

K. Corrosion Protective Coating: A material applied to the prestressing steel to protect the steel from corrosion.

L. Final Effective Force: Force remaining in prestressing steel after all losses have occurred.

M. Hand Seating Tool – A small handheld device used to properly align (seat) the wedges in the anchor prior to attaching the jack to the strand for stressing.

N. Initial Tensioning Force: The initial force that is applied to a barrier cable that will result in the retention of the minimum final effective force as specified by the Engineer of Record.

O. Inserts: Internally threaded device designed to connect certain types of anchorages to the column.

P. Intermediate anchorage: An added anchorage at a point along the length of a barrier cable intended to reduce deflection due to design loading.
Q. Jack: A mechanical device used for applying stressing force to the barrier cable.

R. Jack Grippers: Wedges used in the jack to hold the strand during the stressing operation.


T. MUTS: Minimum Ultimate Tensile Strength.

U. Nose piece: The front part of the jacking devices that fits into the stressing pocket, to align the jack with the anchor.

V. Pocket Former: A temporary device used at the stressing end to provide a cavity that can be grouted after the prestressing operation is complete.

W. Seating Loss: The relative movement of the wedges into the anchor cavity during the transfer of the prestressing force to the anchorage, resulting in some loss of prestressing force.

X. Strand: High-strength prestressing steel wires helically placed around a center wire.

Y. Stressing Equipment: Consists of a properly calibrated jack and pressure gauge with pump and hose.

Z. Wedges: Pieces of tapered metal with serrations, which bite into the prestressing strand during transfer of prestressing force.

AA. Wedge Set: See Seating Loss.

BB. Yield Strength: the stress at which a material exhibits a specific limiting deviation from the proportionality of stress to strain.

1.05 SUBMITTALS

A. Shop Drawings: Installation drawings including plans, elevation, section, details, and note stating that the shop drawings were prepared by or under the supervision of an installer qualified per 3.01, detailing barrier cable layout and installation procedures including the following:

1. Cable run arrangement, length, anchor location, anchor details and designation of barrier cables. Installation and fabrication details of all angles, posts or fabricated steel members needed and their anchoring into the structure.

2. Stressing procedures and jacking forces to result in the final effective forces.

B. Calculations shall be submitted and stamped by a Professional Civil or Structural Engineer licensed in the state of Washington and produced in accordance with the International Building Code and Post-Tensioning Institute, and provide a minimum of the following:

1. Calculation of tendons minimum force for anti-sag criteria.

2. Calculation of tendons maximum force under design loads and verification of acceptance criteria for each cable run.

3. Verification of the maximum deflection criteria for the barrier under the design load for each significant cable.

4. Determination of the pre-tensioning requirements to cover all criteria above including losses unless a specific procedure is in place to compensate for seating losses.
5. Provide a load summary of permanent/accidental forces applied by the barrier for verification of their acceptability by the Engineer of Record.

6. Design calculations for all steel posts, angles or hardware used in the construction of the barrier cable. Design should be based on design loads including direct force on steel posts used in the barrier construction.

C. Operation and Maintenance Manual: The system installer shall submit a system maintenance and operations guide to Sound Transit providing a minimum of the following data:
   1. Recommended inspection periodicity and procedures
   2. Maintenance and repair procedures for minor damage
   3. Action plan in case of major damage impairing the system functionality

1.06 TRANSMITTALS

A. Certified Mill Test Reports shall be transmitted upon request for each coil, reel, or pack of strand containing as a minimum the following information:
   1. Type and Grade
   2. Coil Number
   3. Ultimate Tensile Strength
   4. Nominal Diameter and Steel Area of Strand
   5. Modulus of Elasticity

B. Hardware Data Sheets shall be transmitted for each hardware component used in the cable anchoring system.

C. Stressing records shall be transmitted and filled out by testing agency during stressing operations on the cable systems:
   1. Name of the project
   2. Date of approved installation drawings used for installation and stressing
   3. Date of stressing operation
   4. Weather conditions including temperature and rainfall
   5. Name of the individual in charge of stressing operation
   6. Serial or identification numbers of jacks and gauge
   7. Date of jack and gauge calibration certifications
   8. Gauge pressure to achieve required stressing force per supplied calibration chart
   9. Tendon identification mark
   10. Actual gauge pressure
   11. Representative photographs
PART 2 - PRODUCTS

2.01 PRESTRESSING STEEL

A. Prestressing steel used for barrier cable shall be seven-wire steel strand which consist of one center wire with six wires spirally wrapped around it. For vehicular applications, strand nominal diameter shall be at least ½” and MUTS of 250 ksi or better. Single wires before galvanizing shall meet the requirements of ASTM A 416, grade 250.

B. All exposed barrier cable elements shall be galvanized. Zinc coating shall be produced to comply with ASTM specification A 475 Class A, table 2 coating weight. Galvanized coatings shall be applied by either hot-dip or electro plating process to ensure complete zinc around each individual wire of the strand.

C. Use of polyethylene (plastic) or epoxy coated strands shall be prohibited.

D. Strand pack reels or coils shall be identified at the source as to grade, coil number and type.

E. Acceptance Criteria:

1. Strand used for barrier cable shall meet the minimum requirement of the appropriate ASTM specification as the project specification. No exception will be permitted.

2. The galvanized coating used for the barrier cable shall be free of damage so that the uncoated steel is not exposed to the elements. Cracked or brittle coating shall be rejected.

3. Small areas of damage may be repaired using the manufacturer’s recommended methods provided such repair methods have been approved by the engineer of record. Repair materials and methods shall be compatible with the coating material.

2.02 ANCHORAGE

A. Vehicle barrier systems shall have anchorages or attachments capable of transmitting vehicle loads to the structure. The licensed design professional shall design each component of the anchorage system to resist the loads that will result from both the applied prestressing force and the vehicle loads. The anchorage system includes the barrier cable terminations, the supporting structural member, and any hardware used to attach the barrier cable to its supporting structural member.

B. Wedge type anchorage systems designed to develop at least 95% of the minimum ultimate breaking strength of the barrier cable strand, and complying with the requirements of PTI's Specification of Single Strand Unbonded Tendons shall be used at the termination of each barrier cable to attach the cable to its support member. The anchor (casting or machined barrel anchor) and the wedge shall be considered as one unit. Component parts from different manufacturers shall not be mixed without submitting substantiating test data to the Engineer of Record and obtaining a written approval prior to the application.

2.03 BARRIER CABLE HARDWARE AND EMBEDS

A. Encapsulated Anchors: Castings shall be nonporous and free of sand, blow holes, voids, and other defects. Casting shapes may be rectangular square, or cylindrical with a conical hole designed to receive the matched tapered wedges. Both the casting machined barrel anchors are used in the same way and should be rated to meet the load requirement specified.
B. Inserts shall be cast or drilled into the support member. All inserts shall meet the ultimate pull out and shear load requirements of the building code.

2.04 WEDGES

A. Wedges are made from carbon steel bar and are hardened by heat treatment after the indentations are machined on the inside and is designed to penetrate and hold the barrier cable. The wedges must be under sufficient force to have the teeth engaged into the barrier cable to ensure proper working action of barrier cable systems. The procedures used to accomplish this task must never exceed maximum lateral force allowed by the column. Wedges shall be zinc plated or galvanized for corrosion resistance.

2.05 BEARING PLATES

A. When required by design, a steel plate shall be used. The steel plate shall meet ASTM A36. Size and thickness will be adjusted to meet the design requirement.

2.06 FABRICATED STRUCTURAL STEEL MEMBERS

A. Brackets or steel posts used as attachments to structural members shall be designed to handle both the applied prestressing force and the forces resulting from design loads. The ultimate strength of such devices shall include the mechanical properties of the steel, ultimate pull out and shear load ratings of the hardware and/or welds used in attaching the device to the supporting structural member.

PART 3 - EXECUTION

3.01 QUALIFICATIONS

A. Barrier cable system shall be installed in accordance with the following:

1. The system shall be designed in its entirety under the responsibility of the specialty barrier cable system company.
2. The professional engineer producing the system design calculations shall have a minimum experience of five (5) years and ten (10) barrier cable projects of similar size and scope.
3. The installation shall be performed by a PTI Certified Level 2 Installer of Unbonded Post-Tensioning with a minimum experience of five (5) years and ten (10) barrier cable projects of similar size and scope.
4. Proper calibrated stressing equipment shall be supplied for the application and/or barrier cable systems that are necessary to perform the work. Calibration requirements listed in PTI’s Specification for Unbonded Single Strand Tendons shall be followed.

B. Prequalified Vendors:

1. Dywidag-Systems International, USA Inc.
2. Approved equal satisfying paragraph 3.01 requirements above.

3.02 CAST-IN AND BARREL ANCHORS

A. Cast-in and barrel anchors shall be stressed with a hydraulic stressing jack to provide the specified tension in the cable after all seating losses. Backstressing according to Section 3.06 is required to assure proper wedge seating.
3.03 ADJUSTABLE ANCHORAGE

A. Wedges shall be initially seated at 80% MUTS into the barrel housing to ensure engagement of the wedge teeth into the barrier cable. The final force of the barrier cable may be achieved mechanically through the threading adjustment at the stem of the anchoring device into the insert. The cable installed in these devices shall be backstressed in accordance with Section 3.06 either before or after the installation of the anchor.

3.04 INSTALLATION OF BARRIER CABLE THROUGH COLUMN

A. At intermediate columns, provide sleeves ensuring a hole which is a minimum 1/8” diameter larger than the barrier cable diameter used (including coating material). Spacing and position of the cables shall be executed by the concrete contractor to match the dimensions given by the vehicular barrier cable shop drawings. Errors resulting from misunderstanding or lack of compliance with the barrier cable system drawings shall be repaired by the concrete contractor prior to systems erection.

B. At the end columns, anchors shall be recessed in the column prior to concrete placement or shall bear against the column surface (barrel anchor type). Position, spacing and reinforcing defined in the shop drawings shall be installed by the concrete contractor per the barrier cable system shop drawings.

3.05 STRUCTURAL STEEL ANGLES & COLUMNS

A. Where applicable, structural steel support or anchoring angles shall be installed on the face of the column. These structural members shall be located far enough from the edge of the column so as not cause concrete spalling or cracking when the cables are stressed. The connections to the column shall develop the maximum design load for all the barrier cables at the location.

B. Where applicable, structural steel support or anchoring columns shall be installed as shown in the shop drawings. These structural members shall be positioned in the proper alignment to avoid kinks in the barrier strands. Steel columns shall be anchored to the structure prior to the cable installation and shall not deflect under the barrier loads.

3.06 STRESSING CONSIDERATIONS

A. The licensed design engineer shall specify the minimum final effective force required (after backstressing).

B. All barrier cables shall be stressed to the stressing forces defined in the project approved shop drawings.

C. All anchorages shall be backstressed. This backstressing procedure is performed after the cable is stressed. The jack is removed after the initial tensioning force is achieved and placed so that the jack nose is bearing on the opposite side of the bearing member. The cable shall then be stressed at a force equal to 80% of the MUTS of the strand. In concrete applications, it is necessary to use a slotted plate or other special nose piece to prevent damage to the concrete.

3.07 FINISHING OF ANCHOR RECESSES

A. Barrier cable tails shall be removed within 1 inch from the face of the column using either an oxyacetylene torch, a metal cut off saw, a hydraulic shear, or a plasma cutting device. This operation shall not be perform in rainy weather.

B. Anchor recessing shall be filled with non-metallic non-shrink grout as soon as practical, and shall be applied in one continuous application. Under no circumstances shall the grout
used for this purpose contain chlorides or other chemicals known to be deleterious to the steel.

C. Prior to installing the grout, the inside recessed concrete surfaces shall be cleaned to remove laitance or grease in order to enhance the bond of the grout.

3.08 FINAL INSPECTION & PROTECTION OF BARRIER CABLE SYSTEMS

A. Barrier cable zinc coating damaged during installation, including back-stressing operations or tail cutting shall be repaired with a cold galvanizing spray.

B. At anchorage columns, barrier cable that passes through a hole in the column to anchorage shall have the hold sealed to prevent water from following a path of barrier cable to the anchorage unless the barrier cable slope prevents that from happening.

C. When cable tension is in question, tension verification will be performed by means of an approved cable tension gauge without removing or damaging the cables.

D. Independent special inspection is required to ensure barrier cable system is installed in accordance with the contract and installation drawings. Special inspector shall ensure that the requirements of 1.03.A.2 are met. Special inspector shall submit inspection report to Sound Transit.

3.09 WARRANTY

A. At the completion of the project, the barrier cable system supplier shall provide a written warranty letter for a minimum period of five (5) years on all materials, components and their installation.
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for surface preparation and application of the following:

1. Graffiti-resistant coatings and films to exterior surfaces.
2. Water repellents for interior and exterior wall surfaces.
3. Water repellent sealers for exterior traffic surfaces, and interior floor surfaces.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Washington State Air Quality Rules and Laws
   a. Chapter 173-490 WAC Emission Standards and Controls for Sources Emitting Volatile Organic Compounds (VOC)
   b. Chapter 70.94 RCW Washington Clean Air Act

1.03 SUBMITTALS

A. Product Data: Provide product description. Include data substantiating that material is recommended by manufacturer for applications indicated.

B. Samples: Provide graffiti-resistant film samples as part of Submittals requirements specified in glazing.

C. Manufacturer’s Installation Instructions: Indicate special procedures and conditions requiring special attention; cautionary procedures required during application.

D. Test sample and results, and field inspection reports.

E. Installer Qualification Data: From manufacturer, indicating Applicator complies with requirements.

F. Maintenance Data: In addition to requirements stated elsewhere, include graffiti removal and cleaning instructions with written and video or digital medium showing cleaning procedure, including recommended proprietary products.

G. Warranties: Samples of each manufacturer’s warranties.

1.04 QUALITY ASSURANCE

A. Source Limitations: Obtain graffiti protection materials through one (1) source from a single manufacturer. Provide secondary materials as cleaners recommended by manufacturer of primary materials.
B. Applicator's Qualifications: Company specializing in performing the work of this Section approved by manufacturer, and employing experienced persons trained and approved by repellent manufacturer for application of materials and issuance of special warranty.

C. Graffiti-Resistant Plastic Film Installer Qualifications:

1. Single Installer with a minimum of five (5) years demonstrated experience in installing products of the same type and scope as specified, and trained and approved by the manufacturer for products indicated.

   a. Provide a commercial building reference list of five (5) properties where the installer has applied window film. Include the following information:

      1) Name of building.
      2) The name and telephone number of a management contact.
      3) Type of glass.
      4) Type of film.
      5) Amount of film installed.
      6) Date of completion.

1.05 TEST SAMPLES

A. Prior to preparing mock-ups, obtain and test samples required by the manufacturer for laboratory evaluation in accordance with warranty requirements.

B. Prepare and submit reports.

1.06 MOCK-UPS

A. Prepare a representative surface 6 feet by 6 feet in size using specified materials.

B. Demonstrate preparation and application of repellents and coatings on each type of surface, identical to those to be coated, to establish standards for workmanship and aesthetic effects.

   1. Indicate surface preparation procedures, coverage rates, application methods equipment.
   2. Notify Resident Engineer, 24 hours in advance of tests.
   3. Demonstrate materials and methods to be employed for the removal of spray paint, felt marker, lipstick, paint balls and grease on graffiti-resistant coatings.
   4. Cleaned surface of graffiti-resistant coatings shall be undamaged, and free of "shadows," "ghosts" or similar defects in appearance.

C. Locate mock-ups where directed by Resident Engineer.

D. Approved mock-ups may remain as part of the Work.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials to site in sealed, original, labeled containers bearing manufacturer's name, type of material, brand name, and instructions for mixing. Store materials off-
ground, and under cover. Conform to additional manufacturer’s written instructions regarding storage and handling of materials.

B. The Resident Engineer reserves the right to inspect the containers prior to their opening, to review accompanying bills of lading, and to reject materials in opened containers.

1.08 PROJECT CONDITIONS

A. Weather and Substrate Conditions: Do not proceed with application of repellents and coatings when the following conditions exist, unless otherwise indicated in manufacturer’s written instructions

1. Ambient temperature is less than 40 degrees Fahrenheit or above 100 degrees Fahrenheit.

2. When rain or temperatures below 40 degrees Fahrenheit are predicted for a period of 24 hours, or earlier than three (3) days after surfaces become wet from rainfall or other moisture sources.

3. When substrate is frozen, or at surface temperature of less than 40 degrees Fahrenheit.

4. When winds are sufficient to carry airborne chemicals to unprotected surfaces or adjacent properties, or would cause an improper application rate.

1.09 WARRANTY

A. Special Warranty: Five years for Graffiti-Resistant Film

PART 2 - PRODUCTS

2.01 MATERIALS, GENERAL

A. Compatibility: Repellent and coating materials shall be compatible with substrate surfaces and other materials they are in contact with.

B. Maximum VOC Content: Comply with referenced Washington State Air Quality Rules and Laws.

2.02 NON-SACRIFICIAL GRAFFITI-RESISTANT AND WATER REPELLENT FOR EXTERIOR CONCRETE AND MASONRY WALLS

A. Description: RTV Silicone resin based, penetrating type, 15 percent solids content: maximum 250 g/L VOC content, colorless.

B. Acceptable Product: Subject to compliance with requirements provide one of the following:


2. ProSoCo, Inc. “Blok-Guard & Graffiti Control Ultra 15”

2.03 WATER REPELLENT FOR FLOOR TILES, INTERIOR CONCRETE AND MASONRY WALLS AND CONCRETE DECKS – NON-VEHICULAR TRAFFIC

A. Description: Clear, modified silane/siloxane penetrating solution; low volatility, containing 100 percent alkytrialkoxyssilanes; maximum 400 g/L VOC content.

B. Acceptable Products:

1. ProSoCo, Inc.; “SLX100 Water & Oil Repellent >350”.

2.04 EUCO-GUARD 350 WATER REPELLENT FOR ALL OTHER CONCRETE FLOORS

A. Description: Silane, penetrating water repellent, containing 100 percent alkytrialkoxyssilanes; maximum 400 g/L VOC content.

B. Acceptable Products:

1. ProSoCo, Inc.; “SLX100 Water & Oil Repellent >350”.

2. Rainguard Products Company; “MicroSeal”.

2.05 SACRIFICIAL GRAFFITI-RESISTANT FILM FOR GLASS

A. Description: Anti-vandal film composed of three layers of 2-mil polyester (PET) laminated together; optically-clear, distortion-free, sacrificial coating, which when applied, provides a significant resistance to etching and scratching of underlying surface.

B. Acceptable Product:

1. Vandal Shield, Graffiti Removals, Inc., La Habra, CA, 90632; “VS-1200”.

2. 3M “Anti-Graffiti 6”.

3. Llumar “GCL SR PS”.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify existing conditions before starting work, including:

1. Joint sealants are fully cured.

2. Masonry mortar is cured a minimum of 60 days.

3. Surfaces to be coated are dry, clean, and free of efflorescence, oil, or other material detrimental to performance of work.

B. Inspect surfaces in presence of repellent manufacturer’s authorized technical representative and Applicator.

C. Do not proceed with treatment application until unsatisfactory conditions have been corrected.

D. Concrete Substrates: Cure a minimum of 28 days.
3.02 PREPARATION
A. Clean surfaces of dirt, oils, efflorescence, mildew staining, and other contaminants in accordance with manufacturer’s written instructions.

B. Test surfaces for moisture content in accordance with manufacturer’s written instructions. Allow damp or wet surfaces to dry.

C. Remove contaminants using methods acceptable to repellent manufacturer and Resident Engineer.

D. Notification Prior to Final Application: Notify Resident Engineer at least 24 hours in advance of performing work to witness final application. Clearly mark panels, which have received test applications.

E. Protection of Surfaces:
   1. Protect adjoining work from spillage or overspray of repellents. Cover adjoining and nearby surfaces of aluminum, glass and planting where there is possibility of graffiti-resistant coatings being deposited on surfaces. Cover surface mounted items.

   2. Clean treatments from unintended surfaces immediately after spillage or overspray. Comply with manufacturer’s recommendations for cleaning. Cleaning materials and methods employed shall be such so as not to damage surfaces and permanent finishes.

3.03 WATER AND GRAFFITI REPELLENT APPLICATION
A. Apply repellents in accordance with manufacturer's directions

B. Ensure thorough saturation of porous surfaces of concrete and similar surfaces. Do not dilute or alter materials.

C. Apply repellents at coverage rates and in number of coats determined on test applications.

D. Apply treatment evenly until surfaces are fully wet, starting at the bottom and working up with a 6 to 8 inches rundown below the contact point of the spray pattern, unless otherwise recommended by repellent manufacturer.

E. Finished surface to be even, uniform in texture and appearance and free of runs and drips.

F. Use brushes or rollers where spray method may damage adjacent surfaces.

3.04 GRAFFITI-RESISTANT FILM APPLICATION
A. Preparation:
   1. Clean glass surfaces thoroughly prior to installation.

   2. Prepare surfaces using the methods recommended by the manufacturer for achieving the best result for the substrate under the project conditions.

B. Install film in accordance with manufacturer's instructions.
   1. Cut film edges neatly and square at a uniform distance of 1/8 inch to 1/16 inch of window sealant. Use new blade tips after three to four cuts.
2. Spray the slip solution, composed of one capful of baby shampoo or dishwashing liquid to one gallon of water, on window glass and adhesive to facilitate proper positioning of film.

3. Apply film to glass and lightly spray film with slip solution.

4. Squeegee from top to bottom of window. Spray slip solution to film and squeegee a second time.

5. Bump film edge with lint-free towel wrapped around edge of a five-way tool.

C. Upon completion of film application, allow 30 days for moisture from film installation to dry thoroughly, and to allow film to dry flat with no moisture dimples when viewed under normal viewing conditions.

D. After application of film, wash film using common window cleaning solutions, including ammonia solutions, 30 days after application. Do not use abrasive type cleaning agents and bristle brushes to avoid scratching film. Use synthetic sponges or soft cloths.

3.05 FIELD QUALITY CONTROL

A. Manufacturer’s Field Services: Engaged repellent manufacturer’s factory-trained, authorized technical representative to perform field inspections and tests.

1. Arrange for Resident Engineer and Applicator to be present during tests.

2. Tests: Determine suitable application to each type of substrates before installation. Review substrate conditions, surface preparation procedures, coverage rates, application methods equipment. Notify Resident Engineer, 24 hours in advance of tests.

3. Inspections during Application: Representative to be present during first day of application and periodically as recommended by manufacturer to ensure compliance of quality of execution of manufacturer’s written instructions.

a. Review exposed substrates prior to application.

4. Prepare and submit inspection test reports, and coordinated in accordance with warranties.

3.06 PROTECTION OF FINISHED WORK

A. Protect treated surfaces from traffic, rain, and other surface water in accordance with repellent manufacturer’s written instructions.

3.07 CLEANING

A. Remove and dispose of masking and protective materials.

B. Remove over spray from adjacent surfaces with cleaner as recommended by the repellent manufacturer without damage to surfaces.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for sealant and backing materials for sealing of joints in construction. In general this includes, but is not limited to, the following:

1. All locations noted on Contract Drawings as sealant or caulking.
2. Penetrations in exterior metal wall panel systems.
3. Perimeter joints between materials listed above and door frames, aluminum windows and, louvers.
4. Horizontal/Vertical expansion joints.
5. Perimeter joints between interior wall surfaces and frames of doors, and windows.
6. Tape for isolation and gasketing as indicated.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

B. American Architectural Manufacturers Association (AAMA)
   1. AAMA 800 - Voluntary Specifications and Test Methods for Sealants

C. American Society for Testing and Materials International (ASTM)
   1. ASTM C834 - Standard Specification for Latex Sealants
   2. ASTM C920 - Specification for Elastomeric Joint Sealants
   5. ASTM C1330 - Standard Specification for Cylindrical Sealant Backing for Use with Cold Liquid-Applied Sealants

D. Underwriters Laboratories Inc. (UL)
   1. UL 94 HF-1 - Measure of a material's flammability or burning time before self-extinguishment (burning stops within 2 seconds; afterglow less than 30s; no burning drips allowed).

1.03 SUBMITTALS

A. General: Identify areas of use by each product submitted according with Sealant Schedule in this Section.
B. Product Data: Submit manufacturer's technical data for each joint sealer product required, including instructions for joint preparation, primer (if required), and recommended back-up material.

C. Samples for Initial Selection: Submit initial color samples in the form of manufacturer's bead samples consisting of strips of actual products showing full range of colors available for each product.

D. Certification: Submit written certification from sealant manufacturer stating that materials forming joint substrates and joint backings (e.g., concrete, fluoropolymer coatings) have been tested for compatibility and adhesion with proposed joint sealants and are suitable for the use intended as specified; certification shall state that proposed sealant has been tested for non-staining characteristics when applied to precast concrete. Include recommendations for primers and substrate preparation needed to obtain adhesion.

E. Adhesion Test Log: Submit sample of test log containing requirements listed in Article 3.04.

1.04 QUALITY ASSURANCE

A. Single Source Responsibility: Obtain joint sealant materials for each application from a single manufacturer.

B. Preconstruction Compatibility and Adhesion Testing: Prior to installation of joint sealants, field test their adhesion to joint substrates of each type encountered, and determine if priming and other specific joint preparation techniques are required. Perform tests under normal environmental conditions that will exist during actual installation in accordance with Field Quality Control requirements in this section. Schedule sufficient time for testing and analysis of results to prevent delay in the progress of the Work.

1.05 WARRANTY

A. Special Installer's Warranty: Installer agrees to repair or replace joint sealants that do not comply with performance and other requirements specified in this Section within specified warranty period.

1. Warranty Period: Two (2) years from date of Substantial Completion.

B. Special Manufacturer's Warranty: Manufacturer agrees to furnish joint sealants to repair or replace those joint sealants that do not comply with performance and other requirements specified in this Section within specified warranty period.

Warranty Period: Five (5) years from date of Substantial Completion

1.06 PROJECT CONDITIONS

A. Environmental Conditions: Do not proceed with installation of joint sealants under the following conditions:

1. Ambient and substrate temperature conditions are outside the limits permitted by joint sealant manufacturer.

2. Joint substrates are wet due to rain, condensation or other causes.

3. Joint Width Conditions: Do not proceed with installation of joint sealer when joint widths are less than or larger than allowed by joint sealant manufacturer for application indicated.
4. Joint Substrate Conditions: Do not proceed with installation of joint sealants until contaminants capable of interfering with their adhesion are removed from joint substrates.

PART 2 - PRODUCTS

2.01 MATERIALS, GENERAL

A. Compatibility: Provide joint sealants, joint fillers, and other related materials that are compatible with one another and with joint substrates under conditions of service and application, as demonstrated by sealant manufacturer based on testing and field experience.

B. Color And Texture Criteria (Exterior Exposed to View Locations): Unless noted otherwise provide color of joint sealant selected from manufacturer’s standard colors to match adjacent colors.

C. Color Coated (PVDF) Aluminum Framing: Provide custom color to match the Resident Engineer’s approved (PVDF) color sample.

D. Sealants (Type C) used in horizontal applications shall match adjacent material color.

2.02 SEALANT TYPES AND MANUFACTURERS

A. Type "A" Sealant: Dow Corning "795 Building Sealant"; General Electric "Silglaze SSG4000"; Tremco “Spectrum 2”; or approved equal one-part, low-modulus silicone elastomeric sealant meeting requirements of ASTM C920, Type S, Grade NS, Class 25.

   1. Application: Exposed exterior vertical and horizontal joints not subject to foot or vehicle traffic.

B. Type “B” Sealant: Self-leveling 2-part urethane meeting requirements of ASTM C920, Type M, Grade P, Class 25.

   1. Application: Interior and exterior horizontal joints subject to foot or vehicle traffic.


   1. Applications: Metal to metal open joints, either back groove or top of surface mounted flashing, exposed to weather, and for bedding thresholds and break formed flashings.

D. Type "D" Sealant: Geocel "834"; Pecora Chemical Corporation "AC-20 Acrylic Latex"; Sonneborn "Sonolac"; Tremco "Tremflex 834"; Sherwin-Williams “Pro Select 850A”, or approved equal one part acrylic latex sealant complying with requirements of ASTM C834.

   1. Applications: Interior joints not subject to traffic, and not in wet areas.

   a. Joints in gypsum drywall, concrete, and masonry.

   b. Wall and ceiling control joints.

   c. Other interior joints for which no other type of sealant is indicated.

E. Type "E" Sealant: Dow Corning “786 Mildew Resistant Silicone”; General Electric "SCS1702"; Pecora Corporation "898 Sanitary Mildew Resistant Silicone Sealant", or
approved equal one part mildew resistant silicone sealant complying with requirements of ASTM C920, Type S, Grade NS, Class 25.

1. Applications: Interior joints in wet areas (perimeter of countertops with sinks)

F. Type "F Series" Sealants: Non-curing, non-hardening, synthetic rubber sealer, recommended for use by manufacturer where concealed joints are subject to changes in temperature, water and vibration.

1. Type "F-1": Tape consistency, solvent-free, butyl-based sealant with a solids content of 100 percent; meeting the requirements of AAMA 804.1-85 (as described in AAMA 800). Packaged in rolls with release paper backing.
   a. Acceptable products include:
      1) Tremco "440 Tape".
      2) Pecora, "Extru-Seal".
      3) PTI "606 Architectural Sealant Tape".
   b. Applications: Exterior metal to metal, and dissimilar materials, compression joints subject to shear.

2. Type "F-2": Mastic consistency, one-part non-drying, non-hardening, non-bleeding and permanently resilient butyl sealant, meeting or exceeding ASTM C 1311.
   a. Acceptable products include:
      1) Bostik 5612
      2) Pecora, “BR-96”.
      3) Tremco ‘JS-773 Sealant”.
   b. Applications: Exterior metal to metal laps, concealed compression joints, door thresholds, bottom of steel stud tracks.

2.03 SECONDARY SEAL

A. Application: Compression seal to provide watertight secondary seal and resist air pressure differential behind primary sealant and backer-rod at elevator hoistway joints.

B. Refer to Drawings for size of joint.

C. Acceptable Products include:
   1. Emseal, Backerseal.

2.04 TAPES

A. PVC Tape (Type "G"): Norton Norseal V740, or approved equal black PVC with self-adhesive backing; 1/8 inch thickness by 1/2 inch, nominal width, unless noted otherwise.
   1. Typical application: Gasket/sealant to reduce air movement, acoustical and vibration isolation and between dissimilar materials and elsewhere indicated.
2.05 COMPRESSIBLE SEAL
A. Expanding Foam Tape (Type “H”): Sandell Mfg. Co. Inn., “Polyseal”, Bosig “Wintape Expand 600”, or approved equal, self-expanding polyurethane foam impregnated with modified acrylic flame retarding polymer meeting UL 94 HF-1 (Self-Extinguishing).
   1. Typical application: For cold joints on exterior envelope components, interior side of window to WAB.

2.06 ACOUSTICAL SEALANT
A. Acoustical Sealant (Type "J"): One-part, resilient and non-setting. Spray-on sealants are not acceptable.

2.07 RELATED MATERIALS
A. Plastic Foam Backer Rod: ASTM C 1330. Preformed compressible, resilient, non-waxing, non-extruding foam, of size, shape and density to suit various conditions and control sealant depth and width. Provide open or closed cell as recommended by sealant manufacturer.
B. Backer rod type recommended for compatible with sealant by sealant manufacturer, and of type which does not cause staining or discoloration of joint based on field experience and laboratory testing.
C. Sizes as recommended by sealant manufacturer, with diameter never less than 30 percent greater than width of joint.
D. Bond Breaker Tape: Polyethylene tape or other plastic tape as recommended by sealant manufacturer for preventing bond between sealant and back surface of joint. Provide self-adhesive tape wherever applicable.
E. Primer: Provide type recommended by joint sealer manufacturer where required for adhesion of sealant to joint substrates indicated.
F. Cleaners for Nonporous Surfaces: Provide non-staining, chemical cleaner of type acceptable to manufacturer of sealant and sealant backing materials, which are not harmful to substrates and adjacent nonporous materials, and which do not leave oily residues or otherwise have a detrimental effect on sealant adhesion or in-service performance.

PART 3 - EXECUTION
3.01 EXAMINATION
A. Examine joints indicated to receive joint sealants, with Installer present, for compliance with requirements for joint configuration, installation tolerances and other conditions affecting joint sealant performance. Do not proceed with joint sealer work until unsatisfactory conditions have been corrected.
3.02 PREPARATION

A. Cleaning of Joints: Clean joints immediately before installing joint sealers to comply with recommendations of joint sealer manufacturers and the following requirements:

B. Remove lacquers and protective films from metal surfaces. Clean metal, glass, and other nonporous surfaces by chemical cleaners or other means which are not harmful to substrates or leave residues capable of interfering with adhesion of joint sealants.

C. Jointing Priming: Prime joint substrates where recommended by joint sealer manufacturer based on preconstruction compatibility and adhesion testing or prior experience. Apply primer undiluted in uniform coating over surface. Confine primers to areas of joint sealer bond; do not allow spillage or migration onto adjoining surfaces.

D. Masking Tape: Apply masking tape around joints where required to prevent contact of sealant with adjoining surfaces which otherwise would be stained or damaged by such contact or by cleaning methods required to remove sealant smears. Remove tape immediately after tooling without disturbing joint seal.

3.03 SEALANT APPLICATION

A. General: Comply with joint sealer manufacturer's printed installation instructions applicable to products and applications indicated, except where more stringent requirements apply.

B. Installation Standards: Comply with recommendations of ASTM C1193 for use of joint sealants as applicable to materials, applications and conditions indicated.

C. Installation of Sealant Backings:
   1. Install backer rods in all butt type joints receiving sealant where depth of joint exceeds manufacturer's recommendations. Install joint filler using a blunt tool or plain faced roller. Do not puncture, stretch, or twist joint fillers.
   2. Do not leave gaps between ends of joint fillers. Remove joint fillers that become wet prior to sealant application and replace with dry material.
   3. Generally, install joint fillers to a depth of 1/4 inch below surface of joint. Where depth of joint is not sufficient to require joint filler, install bond breaker tape to cover full width and length of joint cavity to prevent three sided adhesion.

D. Joint Width: Width-to-depth ratio of sealant as recommended by sealant manufacturer. Do not exceed a depth of 1/2 inch when joint is 1/2 inch wide; joints exceeding 1/2 inch in width shall not exceed 1/4 inch in depth.

E. Mixing: Mix two component sealant in accordance with manufacturer's directions using premeasured units. Do not thin or adulterate sealant in any way.

F. Installation of Sealants: Apply sealant over backing to uniform thickness in continuous beads, filling all joints and voids solid; superficial pointing with skim bead will not be accepted. Use nozzle of proper size to completely fill the joints.

G. Tooling of Nonsag Sealants: Immediately after sealant application and prior to time skinning or curing begins, tool sealants to form smooth, uniform beads, free of air pockets; ensure contact and adhesion of sealant with sides of joint. Remove excess sealants from surfaces adjacent to joint.
   1. Provide concave joint configuration, unless noted otherwise.
2. Do not use tooling agents which discolor sealants or adjacent surfaces or are not approved by sealant manufacturer.

H. Pourable sealants shall be applied by gun or by pouring, filling the joint completely with a slight recessed finish. Additional material shall be added if low spots develop. Seal along outside slab edges of joints to prevent water from entering cavity formed by backer rod.

3.04 FIELD QUALITY CONTROL

A. Field-Adhesion Testing: Perform field test of joint sealant in accordance with test recommended in ASTM C1193, except as modified below. Method described is similar to method described in less detail in AAMA's "Aluminum Curtain Wall Series No. 13" and in SWRI's "Sealants: The Professionals' Guide."

1. All testing to be witnessed by Resident Engineer or designated representative.

2. Extent of Testing: Test sealant joints as follows:
   a. Perform single test for each type of sealant and joint substrate for each responsible contractor.
   b. Test joints to be 5 feet long.
   c. Allow sealants to cure fully before testing.

3. Test Method: Test joint sealants by hand-pull method described below:
   a. Make knife cuts from one side of joint to the other, followed by two cuts approximately 2 inches long at sides of joint and meeting cross cut at one end. Place a mark 1 inch from cross-cut end of 2-inch piece.
   b. Use fingers to grasp 2-inch piece of sealant between cross-cut end and 1-inch mark; pull firmly at a 90-degree angle or more in direction of side cuts while holding a ruler alongside of sealant. Pull sealant out of joint to the distance recommended by sealant manufacturer for testing adhesive capability, but not less than that equaling specified maximum movement capability in extension; hold this position for 10 seconds.
   c. For joints with dissimilar substrates, check adhesion to each substrate separately by extending cut along one side, checking adhesion to opposite side, and then repeating this procedure for opposite side.

B. Inspect joints for complete fill, for absence of voids, and for joint configuration complying with specified requirements. Record results in a field adhesion test log.

1. Inspect tested joints and report on the following:
   a. Whether sealants in joints connected to pulled-out portion failed to adhere to joint substrates or tore cohesively. Include data on pull distance used to test each type of product and joint substrate. Compare these results to determine if adhesion passes sealant manufacturer's field-adhesion hand-pull test criteria.
   b. Whether sealants filled joint cavities and are free from voids.
   c. Whether sealant dimensions and configurations comply with specified requirements.
C. Record test results in a field adhesion test log. Include dates when sealants were installed, names of persons who installed sealants, test dates, test locations, whether joints were primed, adhesion results and percent elongations, sealant fill, sealant configuration, and sealant dimensions.

D. Repair sealants pulled from test area by applying new sealants following same procedures used to originally seal joints. Ensure that original sealant surfaces are clean and new sealant contacts original sealant.

E. Evaluation of Field-Test Results: Sealants not evidencing adhesive failure from testing or noncompliance with other indicated requirements, will be considered satisfactory. Remove sealants that fail to adhere to joint substrates during testing or to comply with other requirements. Retest failed applications until test results prove sealants comply with indicated requirements.

3.05 CLEANING

A. Clean off excess sealants or sealant smears adjacent to joints as the Work progresses by methods and with cleaning materials approved in writing by manufacturers of joint sealants and of products in which joints occur.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:
   1. Non-fire-rated steel doors and frames
   2. Fire-rated steel doors and frames
   3. Thermally insulated steel doors
   4. Steel doors with perforated metal infill panel
   5. Accessories, including glazing and matching panels

1.02 REFERENCES

A. This Section incorporates by reference the latest revision of the following documents.
   1. American National Standards Institute (ANSI), International Code Council (ICC)
      b. ANSI A250.8 - SDI-100 Specifications for Standard Steel Doors and Frames
      c. ANSI A250.10 - Test Procedure and Acceptance Criteria for Prime Painted Steel Surfaces for Steel Doors and Frames
      a. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   3. Door and Hardware Institute (DHI)
      a. DHI A115 Series - Specifications for Steel Doors and Frame Preparation for Hardware; Door and Hardware Institute (ANSI/DHI A115 Series)
   4. The National Association of Architectural Metal Manufacturers (NAAMM)
      a. NAAMM HMMA 840 - Guide Specification for Installation and Storage of Hollow Metal Doors and Frames
   5. National Fire Protection Association (NFPA)
a. NFPA 80 - Standard for Fire Doors and Other Opening Protectives

6. Underwriters Laboratories Inc. (UL)
   a. UL 10C – Standard for Positive Pressure Fire Tests of Door Assemblies
   b. UL 1784 - Standard for Air Leakage Tests of Door Assemblies and Other Opening Protectives

1.03 SUBMITTALS

A. Product Data: Materials and details of design and construction, hardware locations, reinforcement type and locations, anchorage and fastening methods, and finishes; and one copy of referenced grade standard.

B. Shop Drawings: Details of each opening, showing elevations, glazing, frame profiles, and identifying location of different finishes, if any. Include installation details for each condition.

C. Transmit: Installation Instructions: Manufacturer's published instructions, including all special installation instructions relating to this project.

1.04 QUALITY ASSURANCE

A. Manufacturer: Company specializing in manufacturing the products specified in this Section with minimum 3 years documented experience.

B. Single Source: Obtain hollow metal doors and frames from a single manufacturer.

C. Maintain at the project site a copy of all reference standards dealing with installation.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Store in accordance with NAAMM HMMA 840.

B. Clearly identify and mark each door and frame to correspond with same number as listed on the schedule submitted with shop drawings.

C. Protect with resilient packaging; avoid humidity build-up under coverings; prevent corrosion.

D. Inspect hollow metal work upon delivery for damage. Minor damages may be repaired provided refinished items are equal in all respects to new work. Remove and replace damaged items as directed by Resident Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Doors and Frames

   1. Requirements for All Doors and Frames:

      a. Accessibility: Comply with ANSI/ICC A117.1
      b. Door Top Closures: Flush with top of faces and edges
      c. Door Edge Profile: Beveled on both edges
d. Door Texture: Smooth faces

e. Infill panels: Non-removable stops on non-secure side. Hardware Preparation: In accordance with DHI A115 Series, with reinforcement welded in place, in addition to other requirements specified in door grade standard.

f. Finish: (Note- choose final finish based on location) Galvanized, unless noted otherwise in door schedule: All components hot-dip zinc-iron alloy-coated (galvannealed), ASTM A653, A40 coating thickness or baked –on primed paint, for field finishing.

2. Combined Requirements: If a particular door and frame unit is indicated to comply with more than one type of requirement, comply with all the specified requirements for each type; for instance, an exterior door that is also indicated as being sound-rated shall comply with the requirements specified for exterior doors and for sound-rated doors; where two requirements conflict, comply with the most stringent.

3. Doors and Frames: Label in accordance with code requirements.

B. Steel Doors

1. Exterior Doors:
   a. Grade: ANSI A250.8 Level 3, physical performance Level A, Model 2, seamless
   b. Galvanizing: All components hot-dipped zinc-iron alloy-coated (galvannealed) in accordance with ASTM A 653/A 653M, with manufacturer's standard coating thickness.

2. Thermal-Rated (Insulated) Doors: For exterior doors enclosing conditioned space provide doors fabricated with thermal-resistance value (R-value) to meet energy code requirements when tested according to ASTM C 1363.

3. Interior Doors, Non-Fire-Rated:
   a. Grade: ANSI A250.8 Level 1, physical performance Level C, Model 1, full flush

4. Interior Doors, Fire-Rated:
   a. Grade: ANSI A250.8 Level 2, physical performance Level B, Model 1, full flush
   b. Fire Rating: As indicated on Door and Frame Schedule, complying with NFPA 80 and tested in accordance with UL 10C ("positive pressure").
      1) Provide units listed and labeled by UL
      2) Attach fire rating label to each fire rated unit
   c. Smoke and Draft Control Doors (Pressure Resistant Doors) (Indicated as "S" in Door Schedule): In addition to required fire rating, provide door assemblies tested in accordance with UL 1784 with maximum air leakage of 3.0 cubic feet per minute per square foot of door opening at 0.10-inch water gage pressure at both ambient and elevated temperatures; with "S" label; if necessary, provide additional gasketing or edge sealing.
1) Grade: ANSI A250.8 Level 3, physical performance Level A, Model 1, full flush

2) Door hardware to conform to door assembly design pressure loads.

5. Panels: Same construction, performance, and finish as doors.

C. Steel Frames

1. General:
   a. Comply with the requirements of grade specified for corresponding door.
      1) ANSI A250.8 Level 3 Doors: Minimum 14 gage frames (typical, unless noted or specified otherwise).
   b. Finish: Same as for door where doors are not factory-finished.
   c. Provide mortar guard boxes for hardware cut-outs in frames to be installed in masonry.
   d. Frames in Masonry Walls: Size to suit masonry coursing with head member 4 inches high to fill opening without cutting masonry units.
   e. Frames wider than 48 Inches: Reinforce with steel channel fitted tightly into frame head, flush with top.

2. Exterior Door Frames: Face welded, seamless with joints filled.
   a. Galvanizing: All components hot-dip zinc-iron alloy-coated (galvannealed) in accordance with ASTM A 653/A 653M, with manufacturer's standard coating thickness.
   b. Weatherstripping/thresholds: Separate, see Section 08 71 00, Door Hardware.

3. Interior Door Frames, Non-Fire-Rated: Fully welded type
   a. Finish: Factory primed, for field finishing

4. Interior Door Frames, Fire-Rated: Fully welded type
   a. Fire Rating: Same as door, labeled

2.02 FRAME ANCHORS

A. Jamb Anchors:
   1. Type: Anchors of minimum size and type required by applicable door and frame standard, and suitable for performance level indicated.
   2. Quantity: Minimum of three anchors per jamb, with one additional anchor for frames with no floor anchor. Provide one additional anchor for each 24 inches of frame height above 7 feet.

B. Floor Anchors: Provide floor anchors for each jamb and mullion that extends to floor.
C. Retain "Floor Anchors for Concrete Slabs with Underlayment" Paragraph below when using flowable underlayment over slabs or floor structure.

D. Floor Anchors for Concrete Slabs with Underlayment: Adjustable-type anchors with extension clips, allowing not less than 2-inch height adjustment. Terminate bottom of frames at top of underlayment.

E. Material: ASTM A 879/A 879M, Commercial Steel (CS), 04Z (12G) coating designation; mill phosphatized.

F. For anchors built into exterior walls, steel sheet complying with ASTM A 1008 or ASTM A 1011; hot-dip galvanized according to ASTM A 153, Class B.

2.03 ACCESSORY MATERIALS

A. Silencers: Resilient rubber, fitted into drilled hole; three on strike side of single door, three on center mullion of pairs, and two on head of pairs without center mullions.

B. Temporary Frame Spreaders: Provide for all factory- or shop-assembled frames

C. Inserts, Bolts, and Fasteners: Hot-dip galvanized according to ASTM A 153

D. Power-Actuated Fasteners in Concrete: Fastener system of type suitable for application indicated, fabricated from corrosion-resistant materials, with clips or other accessory devices for attaching hollow-metal frames of type indicated.

E. Mineral-Fiber Insulation: ASTM C 665, Type I (blankets without membrane facing); consisting of fibers manufactured from slag or rock wool; with maximum flame-spread and smoke-developed indexes of 25 and 50, respectively; passing ASTM E 136 for combustion characteristics.

2.04 FABRICATION

A. Door Astragals: Provide overlapping astragal on one leaf of pairs of doors where required by NFPA 80 for fire-performance rating or where indicated. Extend minimum 3/4 inch (19 mm) beyond edge of door on which astragal is mounted or as required to comply with published listing of qualified testing agency.

B. Glazed Lites: Provide stops and moldings around glazed lites where indicated. Form corners of stops and moldings with mitered hairline joints.

C. Hollow-Metal Frames: Fabricate in one piece except where handling and shipping limitations require multiple sections. Where frames are fabricated in sections, provide alignment plates or angles at each joint, fabricated of metal of same or greater thickness as frames.

D. Hardware Preparation: Factory prepare hollow-metal doors and frames to receive templated mortised hardware, and electrical wiring; include cutouts, reinforcement, mortising, drilling, and tapping according to SDI A250.6, the Door Hardware Schedule, and templates.

E. Reinforce doors and frames to receive nontemplated, mortised, and surface-mounted door hardware.

F. Comply with BHMA A156.115 for preparing hollow-metal doors and frames for hardware.

2.05 FINISH MATERIALS

A. Primer: Rust-inhibiting, complying with ANSI A250.10, door manufacturer's standard and compatible with substrate and field-applied coatings despite prolonged exposure.
1. Siliconized primers are not permitted.

B. Bituminous Coating: Asphalt emulsion or other high-build, water-resistant, resilient coating.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify existing conditions before starting work.

B. Verify that opening sizes and tolerances are acceptable.

3.02 PREPARATION

A. Coat inside of frames with bituminous coating, prior to installation.

B. Coat inside of frames with bituminous coating to a thickness of 1/16 inch.

3.03 INSTALLATION

A. Install in accordance with the requirements of the specified door grade standard and NAAMM HMMA 840.

B. In addition, install fire rated units in accordance with NFPA 80.

C. Coordinate frame anchor placement with wall construction.

D. Install louvers where shown, with tamper proof screws.

E. Install perforated metal infill panels into opening with non-removable stops on non-secure side of door.

F. Grouting Door Frames: Do not grout frames.

G. Fill door frames for exterior concrete and steel stud-framed walls with foam insulation prior to installation.

H. Coordinate installation of hardware.

I. Coordinate installation of electrical connections to electrical hardware items.

J. Field Touch-Up Painting: Touch-up doors and frames including the refinishing of raw surfaces resulting from job fitting, repair of job inflicted scratches and or marred surfaces.

3.04 CONSTRUCTION

A. Erection Tolerances

1. Clearances between Door and Frame: As specified in ANSI A250.8.

2. Maximum Diagonal Distortion: 1/16-inch measured with straight edge, corner to corner.

3.05 ADJUSTING

A. Adjust for smooth and balanced door movement.
3.06 SCHEDULES

A. Refer to Door and Frame Schedule on the Contract Drawings.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:

1. Hardware as indicated and specified herein for hollow steel, aluminum and wood doors, including appropriate fasteners and miscellaneous materials required to complete the Work.

2. Hardware for fire-rated and non-rated doors.

3. Electrically operated and controlled hardware.

4. Lock cylinders for doors for which hardware is specified in other sections.

5. Thresholds.

6. Weatherstripping, seals and door gaskets.

7. Complete hardware schedule preparation. The drawings and specifications are indications of the design intent for the Project. Full provision of an itemized hardware schedule shall be the responsibility of the Contractor.

1.02 REFERENCES

A. This Section incorporates by reference the latest revision of the following documents.


2. ANSI/BHMA A156.18 - American National Standard for Materials and Finishes; Builders Hardware Manufacturers Association, Inc.

3. ANSI/BHMA A156.10: Standard for Power Operated Pedestrian Doors


5. DHI (LOCS) - Recommended Locations for Architectural Hardware for Standard Steel Doors and Frames; Door and Hardware Institute

6. DHI WDHS.3 - Recommended Locations for Architectural Hardware for Flush Wood Doors; Door and Hardware Institute

7. NFPA 80 - Standard for Fire Doors and Other Opening Protectives; National Fire Protection Association


9. UL (BMD) - Building Materials Directory; Underwriters Laboratories Inc.
1.03 SUBMITTALS

A. Hardware Schedules and Product Data

1. Hardware schedules to be in vertical format, listing each door opening, and organized into “hardware sets” indicating complete designations of every item required for each door opening to function as intended. Furnish four (4) copies of revised schedules after approval for field and file use. Note any special mounting instructions or requirements with the hardware schedule. Each schedule to include the following information:

a. Location of each hardware set shall be cross-referenced with on the door schedule on the drawings.

b. Handing and degree of swing of each door.

c. Door and frame sizes and materials.

d. Keying information.

e. Type, style, function, size, and finish of each hardware item.

f. Elevation drawings and operational descriptions for all electrified openings.

g. Name and manufacturer of each hardware item.

h. Fastenings and other pertinent information.

i. Explanation of abbreviations, symbols and codes contained in schedule

j. Mounting locations for hardware when varies from standard.

2. Submit catalog cuts and/or Product Data sheets for all scheduled finish hardware.

3. Submit separate detailed keying schedule for approval.

B. Samples

1. Upon request, samples of each type of hardware in finish indicated shall be submitted. Samples are to remain undamaged and in working condition through submittal and review process. Items will be returned to the Supplier or incorporated into the work within limitations of keying coordination requirements.

C. Templates

1. Furnish a complete list and suitable templates, together with finish hardware schedule to Contractor, for distribution to necessary trades supplying materials to be prepped for finish hardware.

D. Electronic Hardware Systems

1. Provide complete wiring diagrams prepared by an authorized factory employee for each opening requiring electronic hardware, except openings where only magnetic hold-open devices are specified. Provide a copy with each hardware schedule submitted after approval.

2. Provide complete operational descriptions of electronic components listed by opening in the hardware submittals. Operational descriptions to detail how each
electrical component functions within the opening incorporating all conditions of ingress and egress. Provide a copy with each hardware schedule submitted for approval.

3. Provide elevation drawings of electronic hardware and systems identifying locations of the system components with respect to their placement in the door opening. Provide a copy with each hardware schedule submitted for approval.

4. Prior to installation of electronic hardware, arrange conference between Supplier, installers and related trades to review materials, procedures and coordinating related work.

5. The electrical products contained within this specification represent a complete engineered system. If alternate electrical products are submitted, it is the responsibility of the distributor to bear the cost of providing a complete and working system including re-engineering of electrical diagrams and system layout, as well as power transfers and all required electrical components. Coordinate with electrical engineer and electrician to ensure that line voltage and low voltage wiring is coordinated to provide a complete and working system.

6. For each item of electrified hardware specified, provide standardized molex plug connectors to accommodate up to twelve (12) wires. Molex plug connectors shall plug directly into through-door wiring harnesses, frame wiring harnesses, electric locking devices and power supplies.

7. Power supplies are to be provided by the access control subcontractor (Section 28 13 00). Notify Resident Engineer of any proprietary power supply requirements for electronic hardware items provided.

E. Operations and Maintenance Manuals

1. Manuals to include the following items:
   a. Approved hardware schedule, catalog cuts and keying Schedule.
   b. Hardware installation and adjustment instructions.
   c. Manufacturer’s written warranty information.
   d. Wiring diagrams, elevation drawings and operational descriptions for all electronic openings.

1.04 QUALITY ASSURANCE

A. Qualifications

1. Contractor to employ an Architectural Hardware Consultant to coordinate all the hardware requirements for the project including electrified hardware. The Consultant should be currently certified by DHI as an Architectural Hardware Consultant (AHC) and as an Electrified Hardware Consultant (EHC).

2. A recognized architectural door hardware Supplier who has maintained an office and has been furnishing hardware in the Project’s vicinity for a period of at least two (2) years.

3. Hardware Supplier shall be an authorized factory distributor of all products specified herein.
1.05 FIRE-RATED OPENINGS

A. Provide door hardware for fire-rated openings that comply with NFPA 80 and requirements of authorities having jurisdiction. Provide only items of door hardware that are listed by Underwriter’s Laboratories (UL) or Warnock Hersey (WH) for use on types and sizes of doors indicated.

B. Project requires door assemblies and components that are compliant with positive pressure and S-label requirements. Specifications shall be cross-referenced and coordinated with door manufacturers to ensure that total opening engineering is compatible with UL10C Standard for Positive Pressure Fire Tests of Door Assemblies.

1.06 DELIVERY, STORAGE AND HANDLING

A. Marking and Packaging

1. Properly package and mark items according to the approved hardware schedule, complete with necessary screws and accessories, instructions and installation templates for spotting mortising tools. Contractor shall check deliveries against accepted list and provide receipt for them, after which he is responsible for storage and care. Any shortage or damaged good shall be made without cost to the Owner.

2. Packaging of door hardware is the responsibility of the Supplier. As hardware Supplier receives material from various manufacturers, sort and repackage in containers clearly marked with appropriate hardware set and door numbers to match the approved hardware Schedule. Two or more identical sets may be packed in same container.

B. Delivery

1. Hardware Supplier shall coordinate delivery times and schedules with the Contractor for delivery of all door hardware. Inventory door hardware jointly with representatives of hardware Supplier and hardware installer/Contractor until each is satisfied that count is correct.

2. No keys, other than construction master keys and/or temporary keys are to be packed in boxes with the locks.

3. At time of hardware delivery, door openings Supplier in conjunction with the Contractor shall check in all hardware and set up a hardware storage room.

C. Storage

1. Provide secure lock-up for door hardware delivered to the Project, but not yet installed. Control handling and installation of hardware items that are not immediately replaceable so that completion of work will not be delayed by hardware losses both before and after installation.

1.07 WARRANTY

A. All items, except as noted below, shall be warrantied in writing by the manufacturer against failure due to defective materials and workmanship for a minimum period of two (2) years. In the event of product failure, promptly repair or replace item with no additional cost to the owner.

1. Mortise locksets: Five (5) years

2. Electromagnetic locks: Five (5) years
3. Exit Devices: Five (5) years
4. Door closers: Ten (10) years
5. Securitron (and approved equals) electrified hardware: Unlimited Lifetime

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Obtain each type of finish hardware set (hinges, latch and locksets, exit devices, door closers, etc.) from a single manufacturer.

2.02 MATERIALS – All hardware installed for gates shall be 316 Stainless steel marine grade.

A. Screws and Fasteners

1. All required screws shall be supplied as necessary for securing finish hardware in the appropriate manner. Thru-bolts shall be supplied for exit devices and door closers where required by code and the appropriate blocking or reinforcing is not present in the door to preclude their use.

B. Hanging Devices

1. Hinges
   a. Hinges shall conform to ANSI A156.1 and have the number of knuckles as specified, oil-impregnated bearings as specified with NRP (non-removable pin) feature, at all exterior reverse bevel doors. Unless otherwise scheduled, supply one (1) hinge for every 30” of door height, or fraction thereof (*). Hinges shall be a minimum of 4 1/2” high and 4 1/2” wide; heavy weight hinges (.180) shall be supplied at all doors.

   1) Approved manufacturers: McKinney, Bommer, Hager, Stanley

2. Continuous Stainless Steel Hinges
   a. All hinges to be non-handed and of slim barrel design. Hinges to be made of type 304 stainless steel and shall have a concealed teflon-coated stainless steel pin with twin self-lubricated nylon bearings at each knuckle. Hinges shall be UL listed up to and including 3 hours and shall be available with power transfer cutouts when necessary.

   1) Approved Manufacturers: Markar, McKinney, Select

C. Flush Bolts and Accessories

1. All manual and automatic flush bolts to be furnished as specified.
   a. Approved Manufacturers: Rockwood, McKinney, Trimco

D. Cylinders and Keying

1. Construction Cylinders
   a. Manufacturer: To match hardware

2. Permanent Cylinders
a. Provide for Sound Transit Link Light Rail Stations. Cylinders shall be high security tested, drill & pick proof, extreme attack configured, patent protected in U.S. and Canada, and include a unique double row of pins.

1) Approved Manufacturer: BiLock

b. Provide for Parking Garages, Sounder and ST Express facilities. Cylinders shall be high security tested, patent protected in U.S. and Canada, 7-pin interchangeable cores

1) Approved Manufacturer: KABA Peaks

3. Keying

a. All locks and cylinders shall be provided with construction cylinders/cores, for use during the construction phase. All permanent cores shall be keyed to the existing KABA Peaks or BiLock Master key system, per the approved key schedule. All keys shall be serialized. Provide the following quantity of keys:

1) Two (2) change keys per lock
2) Six (6) master keys per master level
3) Five (5) construction/temporary keys
4) Two (2) construction core control keys
5) Two (2) operational control keys

4. Cylinder Installation

a. The general Contractor shall install all construction cylinders/cores at the time of hardware installation.

b. The Contractor shall provide all permanent cylinders/cores to Sound Transit no later than 90 days before install. At no time shall the Contractor be in possession of the final keyed cylinders or keys.

c. The Contractor shall coordinate with Sound Transit for the installation of the final keyed cylinders/cores. Installation of the permanent cylinders/cores will be performed by Sound Transit per the approved key schedule.

5. Key Box

a. Model: KNOX 4400 X Recessed Mounting Kit (RMK)

b. Provide as required by AHJ.

E. Locking Devices

1. Mortise Locksets

a. All locksets shall be ANSI 156.13 Series 1000, Grade 1 Certified. All functions shall be manufactured in a single sized case formed from 12 gauge steel minimum. The lockset shall have a field-adjustable, beveled armored front, with a .125" minimum thickness and shall be reversible without opening the lock body. The lockset shall be 2 3/4" backset with a
one-piece 3/4” anti-friction stainless steel latchbolt. The deadbolt shall be a full 1” throw made of stainless steel and have 2 hardened steel roller inserts. All strikes shall be non-handed with a curved lip. To ensure proper alignment, all trim, shall be thru-bolted and fully interchangeable between rose and escutcheon designs and shall be the product of one manufacturer.

1) Supported Manufacturers: Corbin Russwin, Schlage

2. Electrified Locksets
   a. Mechanical features of locksets shall conform to standards as specified above. Locksets shall be fail-secure unless otherwise specified. Where specified electrified locksets shall be provided with a switch to monitor inside or outside lever handle or signal remote location.

   1) Supported Manufacturers: Corbin Russwin, Schlage

3. Lockset Strikes
   a. Strikes shall be non-handed and available with curved lip, full lip or ASA type strikes as required. Provide strikes with lip-length required to accommodate jamb and/or trim detail and Projection.

F. Exit Devices
  1. Conventional Devices – Push Rail
     a. All exit devices shall be ANSI A156.3, Grade 1 Certified and shall be listed by Underwriters Laboratories and bear the UL label for life safety in full compliance with NFPA 80 and NFPA 101. Mounting rails shall be formed from a solid single piece of stainless steel, brass or bronze no less than 0.072” thick. Push rails shall be constructed of 0.062” thick material. Painted or anodized aluminum shall not be considered heavy duty and is not acceptable. Lever trim shall be available in finishes and designs to match that of the specified locksets.

     1) Approved Manufacturer: Corbin Russwin ED4000/ED5000 Series, Precision

G. Door Closers
  1. Surface-Mounted Closers – Heavy Duty
     a. All door closers shall be ANSI 156.4, Grade 1 Certified. All closers shall have aluminum alloy bodies, forged steel arms, and separate valves for adjusting backcheck, closing and latching cycles and adjustable spring to provide up to 50 percent increase in spring power. Closers shall be furnished with parallel arms mounting on all doors opening into corridors or other public spaces and shall be mounted to permit 180 degrees door swing wherever wall conditions permit. Closers shall not be installed on exterior or corridor side of doors; where possible install closers on door for optimum aesthetics.

     1) Approved Manufacturers: Corbin Russwin DC6000 Series, Norton

     b. Swing door Automatic Door Operators- Electromechanical Operators shall be self-contained unit powered by a minimum 3/16 horsepower,
permanent-magnet DC motor; through a high torque reduction gear system.

1) Operation: Power opening and spring closing.
2) Operator Type: Low energy; readily convertible to full energy; no tools required to change type.
3) Handing: Non-handed; no tools required to change handing.
4) Capacity: Rated for door panels weighing up to 350 lb
5) Approved Manufacturers: AssaAbloy, Stanley.

H. Door Trim and Protective Plates

1. Kick plates shall be .050 gauges and two (2) inches less full width of door, or as specified. All protective plates, door pulls and miscellaneous door trim shall be as shown in the hardware Schedule.
   a. Approved Manufacturers: Rockwood Door Stops and Holders, McKinney, Trimco

2. Wall-mounted Door Stops
   a. Where a door is indicated on the plans to strike flush against a wall, wall bumpers shall be provided. Provide convex or concave design as indicated.
      1) Approved Manufacturers: Rockwood, McKinney, Trimco

3. Overhead Stops/Holders
   a. Overhead stops/holders are to be provided. Track, slide, arm and jamb bracket shall be constructed of extruded bronze and shock absorber spring shall be of heavy tempered steel. Overhead stops shall be of non-handed design.
      1) Approved Manufacturers: Rixson, ABH

I. Gasketing and Thresholds

1. Provide continuous weatherseal on exterior doors and smoke, light, or sound seals on interior doors where indicated or as scheduled. Provide intumescent seals as required to meet UL10C Standard for Positive Pressure Fire Tests of Door Assemblies. Provide only those units where resilient or flexible seal strip is easily replaceable and readily available from stocks maintained by manufacturer.

2. Provide threshold units not less than 4" wide, formed to accommodate change in floor elevation where indicated, fabricated to accommodate door hardware and to fit door frames. All threshold units shall comply with the Americans with Disabilities Act (ADA).
   a. Approved Manufacturers: Pemko, Reese, Zero

J. Door Silencers

1. Furnish rubber door silencers all hollow metal frames; two (2) per pair and three (3) per single door frame.
K. Power Supplies
   a. Power supplies to be provided as part of the access control system. See section 28 13 01 Access Control System.

2.03 HARDWARE FINISHES
   A. 630 Satin Stainless Steel finish required.
   B. The designations used in schedules and elsewhere to indicate hardware finishes are those listed in ANSI/BHMA A156.18 or traditional U.S. finishes shown by certain manufacturers for their products.
   C. Provide quality of finish, including thickness of plating or coating (if any), composition, hardness, and other qualities complying with manufacturer's standards, but in no case less than specified by referenced standards for the applicable units of hardware.
   D. Where specified hardware shall have an antimicrobial coating which permanently suppresses the growth of bacteria, algae, fungus, mold and mildew applied. The finish shall control the spread and growth of bacteria, mold and mildew and shall be FDA listed for use in medical and food preparation equipment.

PART 3 - EXECUTION
3.01 EXAMINATION
   A. Contractor shall ensure that the building is secured and free from weather elements prior to installing interior door hardware. Examine hardware before installation to ensure it is free of defects.

3.02 INSTALLATION
   A. Mount hardware units at heights indicated in the following applicable publications, except as specifically indicated or required to comply with the governing regulations.
      1. “Recommended Locations for Builders Hardware for Standard Steel Doors and Frames” by the Door and Hardware Institute (DHI.)
      2. NWWDA Industry Standard I.S.1.7, “Hardware Locations for Wood Flush Doors.”
   B. All hardware shall be applied and installed in accordance with best trade practice by an experienced hardware installer. Care shall be exercised not to mar or damage adjacent work.
   C. Install each hardware item in compliance with the manufacturer's instructions and recommendations. Where cutting and fitting is required to install hardware onto or into surfaces that are later to be painted or finished in another way, coordinate removal, storage, and reinstallation or application of surface protection with finishing work specified in the Division 9 Sections. Do not install surface-mounted items until finishes have been completed on the substrates involved.
   D. Set thresholds for exterior doors in full bed of synthetic rubber sealant complying with requirements specified in Section 079200, Joint Sealants.

3.03 FIELD QUALITY CONTROL
   A. The Contractor shall do a final inspection prior to building completion to ensure that all hardware was correctly installed and is in proper working order.
3.04 ADJUSTING, CLEANING, AND DEMONSTRATING

A. Adjust and check each operating item of hardware and each door to ensure proper operation or function of every unit. Replace units that cannot be adjusted to operate freely and smoothly or as intended for the application made.

B. Clean operating items as necessary to restore to proper function and finish of hardware and doors. Adjust door control devices to compensate for final operation of heating and ventilating equipment.

C. Instruct owner’s personnel in the proper adjustment and maintenance of door hardware and hardware finishes and usage of any electronic devices.

3.05 PROTECTION

A. Contractor shall protect all hardware, when stored on the construction site ensure that is in a covered and dry place. Protect exposed hardware installed on doors during the construction phase.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:
   1. Metal stud wall framing.
   2. Metal channel ceiling framing.
   3. Shaft wall system.
   4. Fire-rated wall and ceiling assemblies.
   5. Miscellaneous interior subframing as required.
   7. Cementitious backer board.
   8. Joint treatment and accessories.
   9. Acoustic insulation and sealant.
  10. Delegated design of framing systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American National Standards Institute (ANSI)
      a. ANSI A108.4 - American National Standard Specifications for Installation of Ceramic Tile with Organic Adhesives or Water Cleanable Tile Setting Epoxy Adhesive
      b. ANSI A108.9 - American National Standard Specifications for Installation of Ceramic Tile with Modified Epoxy Emulsion Mortar/Grout
      c. ANSI A108.11 - American National Standard for Interior Installation of Cementitious Backer Units
      a. ASTM A653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
      b. ASTM A568/A568M - Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements
c. ASTM B221 - Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes

d. ASTM C475/C 475M - Standard Specification for Joint Compound and Joint Tape for Finishing Gypsum Board

e. ASTM C645 - Standard Specification for Nonstructural Steel Framing Members

f. ASTM C754 - Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products

g. ASTM C840 - Standard Specification for Application and Finishing of Gypsum Board

h. ASTM C1002 - Standard Specification for Steel Self-Piercing Tapping Screws for the Application of Gypsum Panel Products or Metal Plaster Bases to Wood Studs or Steel Studs; 2004

i. ASTM C1047 - Standard Specification for Accessories for Gypsum Wallboard and Gypsum Veneer Base

j. ASTM C1178/C1178M - Standard Specification for Glass Mat Water-Resistant Gypsum Backing Panel

k. ASTM C1396/C 1396M - Standard Specification for Gypsum Board

l. ASTM D3273 - Standard Test Method for Resistance to Growth of Mold on the Surface of Interior Coatings in an Environmental Chamber

m. ASTM E72 - Standard Test Methods of Conducting Strength Tests of Panels for Building Construction; 2005


o. ASTM E488 - Standard Test Methods for Strength of Anchors in Concrete Elements


3. Gypsum Association (GA)


c. GA-226 - Application of Gypsum Board to Form Curved Surfaces; Gypsum Association.


4. Underwriters Laboratories Inc. (UL)

a. UL (FRD) - Fire Resistance Directory.
1.03 SUBMITTALS

A. Shop Drawings: Indicate special details associated with fireproofing, acoustic seals, and other unique details. Show size, gauge, and spacing of studs used to comply with specified requirements for steel framing, and show all control joints as indicated or required in accordance with ASTM C840.

B. Product Data: Provide data on metal framing, gypsum board, accessories, and joint finishing system.

C. Engineering: for Delegated-Design Submittals include analysis data signed and sealed by the qualified professional engineer responsible for their preparation.

D. Provide manufacturer's data or engineering calculations on spans, deflection, attachment methods, and bracing, and indicate compliance with code. Product Data: Provide manufacturer's data on partition head to structure connectors, showing compliance with requirements.

E. Transmit: Test Reports: For all stud framing products that do not comply with ASTM C 645 or C 754, provide independent laboratory reports showing maximum stud heights at required spacing and deflections.

1.04 QUALITY ASSURANCE

A. Single Source Responsibility for Panel Products: Obtain each type of gypsum board and other panel products from a single manufacturer.

B. Single Source Responsibility for Finishing Materials: Obtain finishing materials from the same manufacturer that supplies gypsum board and other panel products.

C. Perform all work of this Section in accordance with ASTM C 840.

D. Applicator Qualifications: Company specializing in performing gypsum board application and finishing, with minimum three years of documented experience.

E. Coordination: Coordinate work with that of other trades, including but not limited to plumbing, HVAC, electrical and fire sprinklers, to ensure complete and proper installation of all trades. Include coordination with and provision for design-build trades in base bid pricing.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials in original packages, containers, or bundles bearing brand name and identification of manufacturer or supplier.

B. Store materials inside under cover and keep them dry and protected against damage from weather, direct sunlight, surface contamination, corrosion, construction traffic, and other causes. Neatly stack gypsum panels flat to prevent sagging.

C. Handle gypsum board to prevent damage to edges, ends, and surfaces. Do not bend or otherwise damage metal corner beads and trim.

1.06 PROJECT CONDITIONS

A. Environmental Conditions, General: Establish and maintain environmental conditions for applying and finishing gypsum board to comply with ASTM C 840 and with gypsum board manufacturer's recommendations.
B. Ventilation: Ventilate building spaces, to the extent required, for drying joint treatment materials. Avoid drafts during hot dry weather to prevent finishing materials from drying too rapidly.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Gypsum Board:


B. Cementitious Backer Board

1. Custom Building Products: www.custombuildingproducts.com
2. James Hardie: www.jameshardie.com

2.02 PERFORMANCE CRITERIA

A. Fire Test Response Characteristics: Where fire-rated gypsum board assemblies are indicated, provide materials and construction identical to those of assemblies tested for fire resistance in accordance with ASTM E 119 by an Independent Testing Laboratory agency acceptable to the authorities having jurisdiction.

B. Fire Resistance Ratings: As indicated by reference to GA file numbers in GA-600 "Fire Resistance Design Manual" or to design designations in UL "Fire Resistance Directory" or in the listing of another Independent Testing Laboratory acceptable to authorities having jurisdiction.

1. Regulatory Requirements
   a. Conform to applicable code for fire-rated assemblies as follows:
   b. Fire-Rated Partitions: Listed assembly by UL or GA with required hour ratings as indicated on Drawings.
   c. Head of Fire-Rated Partitions: Listed assembly by UL or GA with required hour ratings as indicated on Drawings.

2.03 MATERIALS

A. Metal Framing

1. General: Provide steel framing members complying with the following requirements:
   a. Performance Requirements: Select steel studs and all other members in accordance with the manufacturer’s standard load tables and following design pressures and deflections:
      1) At all partitions: 1/360 at 10 pounds per square foot.
2) At suspended and furred ceilings: 1/240 per 10 pounds per square foot.

b. Protective Coating: G40 hot-dip galvanized coating in accordance with ASTM A653.

2. Non-Loadbearing Framing System Components: ASTM C645; galvanized sheet steel, of size and properties necessary to comply with ASTM C754 for the conditions indicated.

a. Exception: The minimum metal thickness and section properties requirements of ASTM C645 are waived provided steel of 40,000 pounds per square inch minimum yield strength is used, the metal is continuously dimpled, the effective thickness is at least twice the base metal thickness, and maximum stud heights are determined by testing in accordance with ASTM E72 using assemblies specified by ASTM C754.

b. Steel Studs and Runners: ASTM C645, with flange edges of studs bent back 90 degrees and doubled over to form 3/16-inch-wide minimum lip (return) and complying with the following requirements for minimum thickness of base (uncoated) metal and for depth:

1) Thickness: As required to comply with performance requirements for horizontal deflection
   a) Depth: As detailed.

c. Steel Rigid Furring Channels: ASTM C645, hat-shaped, depth and minimum thickness of base (uncoated) metal as follows:

1) Depth: 7/8 inch.

2) Thickness: 0.0179 inch, unless otherwise indicated.

d. Furring Brackets: Serrated-arm type, adjustable, fabricated from corrosion-resistant steel sheet complying with ASTM C645, minimum thickness of base (uncoated) metal of 0.0329 inch, designed for screw attachment to steel studs and steel rigid furring channels used for furring.

e. Z-Furring Members: Manufacturer’s standard Z-shaped furring members with slotted or non-slotted web, fabricated from steel sheet complying with ASTM A653 or ASTM A568; with a minimum base metal (uncoated) thickness of 25 GA at interior non load bearing locations, face flange of 1-1/4 inch, wall-attachment flange of 7/8 inch, and of depth required to fit insulation thickness indicated.

f. Fasteners for Metal Framing: Provide fasteners of type, material, size, corrosion resistance, holding power, and other properties required to fasten steel framing and furring members securely to substrates involved; complying with the recommendations of gypsum board manufacturers for applications indicated.


a. Strapping: Provide 16 gauge x 2 inches width strapping at locations indicated on Drawings.
b. Backing: Behind all cabinetry and shelving, provide 16 gauge sheet metal backing, sized to match extent of cabinetry or shelving, inside of walls screwed directly on steel studs before gypsum wallboard is installed. Ensure flat gypsum installation as required by ANSI A108-A4.8. Use “MantisGrip” backing clips where appropriate. www.mantisgrip.com

4. Typical Framing Components:

a. Studs: "C" shaped with flat or formed webs.

b. Runners: U shaped, sized to match studs.

c. Ceiling Channels: C shaped.

d. Furring: Hat-shaped sections, minimum depth of 7/8 inch.

e. Deflection Track: Manufacturer’s deep-leg, U-shaped steel track; unpunched, with unstiffened flanges, of web depth to contain studs while allowing free vertical movement, with flanges designed to support horizontal and lateral loads.

5. Shaft Wall Studs and Accessories: ASTM C645; galvanized sheet steel, of size and properties necessary to comply with ASTM C754 and specified performance requirements.

6. Framing for Suspended and Furred Wallboard Ceilings: Type and size as specified in ASTM C754 for spacing required.

7. Partition Head to Structure Connections: Provide track fastened to structure with legs of sufficient length to accommodate deflection, for friction fit of studs cut short.

B. Gypsum Board

1. GWB-1: ASTM C1177/C1177M, 5/8 inch thick with fiberglass mat laminated to both sides and with manufacturer’s standard edges.

2. GWB-2: Same as GWB-1 except fire rated. Assemblies Indicated with Fire-Rating: Use type required by indicated tested assembly; if no tested assembly is indicated, use Type X board, UL or WH listed.

3. GWB-3: Paper-faced moisture resistant gypsum wallboard as defined in ASTM C1396/C1396M; sizes to minimize joints in place.

4. GWB-4: Gypsum Shaftwall or Coreboard: ASTM C1396/C1396M; Type X core; sizes to minimize joints in place; 1 inch thick; square, tongue and groove, or double beveled edges, ends square cut.

5. CBB-1: Cementitious Backerboard Substrate for Ceramic Wall Tile and Interior Acoustical Cement Plastering.

a. Backerboard: ANSI A118.9; High density, cementitious, glass fiber reinforced. 5/8” thick unless noted otherwise.

b. Mesh Tape: 2-inch wide self-adhesive, coated fiberglass mesh tape for joints and corners.
2.04 ACCESSORIES

A. Sound Attenuation Blankets: Unfaced mineral-fiber blanket insulation produced by combining mineral fibers of type described below with thermosetting resins to comply with ASTM C665 for Type I (blankets without membrane facing):

1. Mineral-Fiber Type: Fibers manufactured from glass or slag.

B. Acoustic Sealant: Non-hardening, non-skinning, non-sag, non-staining, paintable latex sealant, for use in conjunction with gypsum board, and complying with ASTM C834 and the following:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. AC-20 FTR Acoustical and Insulation Sealant, Pecora Corp.
   b. SHEETROCK Acoustical Sealant, United States Gyp Co.

C. Corner Beads, Edge Trim, and Control Joints: Galvanized steel, or plastic, complying with ASTM C1047. Sheet steel zinc-coated by hot-dip process.

1. Shapes indicated below by reference to Fig. 1 designations in ASTM C1047:
   a. Provide metal corner bead on outside corners, unless otherwise indicated on Drawings.
   b. LC-bead with both face and back flanges; face flange formed to receive joint compound. Use LC-beads for edge trim unless otherwise indicated.
   c. L-bead with face flange only; face flange formed to receive joint compound. Use L-bead where indicated.
   d. One-piece control joint formed with V-shaped slot, with removable strip covering slot opening.

D. Aluminum Accessories: Where indicated, provide manufacturer’s standard extruded aluminum accessories of profile indicated or referenced by manufacturer’s product designations, complying with the following requirements:

1. Aluminum Alloy: Alloy and temper recommended by aluminum producer and finisher for type of finish indicated and with not less than the strength and durability properties of aluminum extrusions complying with ASTM B221 for alloy and temper 6063-T5.

2. Class II Clear-Anodized Finish: AA-C12C22A3 1 (Chemical Finish: cleaned with inhibited chemicals; Chemical Finish: etched, medium matte; Anodic

E. Joint Materials: ASTM C475 and as recommended by gypsum board manufacturer for project conditions.

1. Joint Tape: Provide paper reinforcing tape, unless otherwise indicated.

2. Setting-Type Joint Compounds for Gypsum Board: Factory-packaged, job-mixed, chemical-hardening powder products formulated for uses indicated.
   a. Where setting-type joint compounds are indicated as a taping compound only or for taping and filling only, use formulation that is compatible with other joint compounds applied over it.
b. For pre-filling gypsum board joints, use formulation recommended by gypsum board manufacturer for this purpose.

c. For filling joints and treating fasteners of water-resistant gypsum backing board behind base for ceramic tile, use formulation recommended by the gypsum board manufacturer for this purpose.

d. For topping compound, use sandable formulation.

3. Drying-Type Joint Compounds for Gypsum Board: Factory-packaged vinyl-based products complying with the following requirements for formulation and intended use.


c. Taping compound formulated for embedding tape and for first coat over fasteners and face flanges of trim accessories.

d. Topping compound formulated for fill (second) and finish (third) coats.

F. Screws: ASTM C1002; self-drilling type unless otherwise noted. Provide corrosion resistant coated steel drill screws in accordance with manufacturer recommendations at all exterior and wet interior locations.

G. Laminating Adhesive: Special adhesive or joint compound recommended for laminating gypsum panels.

H. Fastening Adhesive for Metal: Special adhesive recommended for laminating gypsum panels to steel framing.

I. Anchorage to Substrate: Corrosion resistant tie wire, nails, screws, fasteners, sealants and other metal supports, of type and size to suit application; to rigidly secure materials in place.

J. Cast-In-Place and Post-Installed Anchors in Concrete: Chemical, Expansion, or Cast in place anchors, fabricated from corrosion-resistant materials, with holes or loops for attaching hanger wires, and with capability to sustain, without failure, a load equal to 5 times that imposed by ceiling construction, as determined from testing in accordance with ASTM E488 conducted by an Independent Testing Laboratory.

K. Powder-Actuated Fasteners in Concrete: Fastener system of type suitable for application indicated, fabricated from corrosion-resistant materials, with clips or other accessory devices for attaching hangers of type indicated, and with capability to sustain, without failure, a load equal to 10 times that imposed by ceiling construction, as determined by testing in accordance with ASTM E1190 conducted by an Independent Testing Laboratory.

L. Wire for Hangers and Ties: ASTM A641, Class 1 zinc coating, soft temper. 0.1620- inch (8 gauge) diameter.

M. Hanger Rods: Mild steel and zinc-coated or protected with rust-inhibitive paint.

N. Flat Hangers: Mild steel and zinc-coated or protected with rust-inhibitive paint.

O. Angle-Type Hangers: Angles with legs not less than 7/8 inch wide, formed from 0.0635 inch-thick galvanized steel sheet complying with ASTM A446 Coating Designation 090, with bolted connections and 5/16-inch-diameter bolts.
P. Elastomeric Spray-Applied Membrane:

1. CP 672 Fire Spray by Hilti Construction Chemicals
2. Metacaulk 1200 and Biostop 750 by Rectorseal

2.05 FABRICATION

A. Gypsum Board Assemblies

1. Provide completed assemblies complying with ASTM C840 and GA-216.

2. Fire Rated Assemblies: Provide completed assemblies with the following characteristics:

   a. Fire Rated Partitions, Ceilings, Soffits, Shaft Walls and Wall Head Conditions: UL listed or GA listed assemblies as detailed or indicated on Drawings on Sheet A581.
   b. ICC IBC Item Numbers: Comply with applicable requirements of ICC IBC for the particular assembly.
   c. Gypsum Association File Numbers: Comply with requirements of GA-600 for the particular assembly.
   d. UL Assembly Numbers: Provide construction equivalent to that listed for the particular assembly in the current UL Fire Resistance Directory.

2.06 FINISHES

A. Gypsum Board

1. Finish gypsum board to the Levels shown in the schedule at the end of Part 3 for different applications. Finish Levels to comply with GA 214-10 "Recommended Levels of Gypsum Board Finish".

2. Finish water-resistant gypsum backing board forming substrate for ceramic tile to comply with ASTM C840 and board manufacturer’s directions for treatment of joints behind tile.

3. Tape, fill, and sand exposed joints, edges, and corners to produce smooth surface ready to receive finishes.

   a. Feather coats of joint compound so that camber is maximum 1/32 inch.

4. Fill and finish joints and corners of cementitious backing board as recommended by manufacturer.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that project conditions are appropriate for work of this section to commence. Examine substrates to which gypsum board assemblies attach or abut, installed hollow metal frames, cast-in-anchors, and structural framing with Installer present for compliance with requirements for installation tolerances and other conditions affecting
performance of assemblies specified in this Section. Do not proceed with installation until unsatisfactory conditions have been corrected.

3.02 PREPARATION
A. Ceiling Anchorages: Coordinate installation of ceiling suspension systems with installation of overhead structural assemblies to ensure that inserts and other provisions for anchorages to building structure have been installed to receive ceiling hangers that will develop their full strength and at spacing required to support ceilings.

1. Furnish concrete inserts and other devices indicated to other trades for installation well in advance of time needed for coordination with other construction.

3.03 METAL FRAMING INSTALLATION
A. Shaft Wall
1. General: Install gypsum board shaft-wall assemblies to comply with performance and other requirements indicated as well as with manufacturer’s installation instructions and the following:
   a. ASTM C754 for installing steel framing.
2. Do not bridge building expansion joints with shaft-wall assemblies; frame both sides of joints with furring and other support as indicated.
3. Install supplementary framing in gypsum board shaft-wall assemblies around openings and as required for blocking, bracing, and support of gravity and pullout loads of fixtures, equipment, services, heavy trim, furnishings, and similar items that cannot be supported directly by shaft-wall assembly framing.
   a. Support elevator hoistway door frames independently of shaft-wall framing assemblies, or reinforce assemblies according to assembly manufacturer’s instructions.
   b. Where handrails are indicated for direct attachment to gypsum board shaft-wall assemblies, provide not less than a 0.0341-inch-thick by 4-inch-wide galvanized steel reinforcement strip, accurately positioned and secured behind not less than 1 gypsum board face layer of 1/2-inch or 5/8-inch thickness.
4. Coordinate gypsum board shaft-wall construction with sprayed-on fireproofing applied to structural elements so both remain complete and undamaged. Patch or replace sprayed-on fireproofing removed or damaged during the installation of shaft-wall assemblies to comply with requirements specified in Division 07 Section “Sprayed-On Fireproofing.”
5. Integrate stair hanger rods with gypsum board shaft-wall assemblies where indicated (and where possible) by locating cavity of assemblies where required to enclose rods.
6. At penetrations in shaft wall, maintain fire-resistance rating of entire shaft-wall assembly by installing supplementary steel framing around perimeter of penetration and fire protection behind boxes containing wiring devices, elevator call buttons, elevator floor indicators, and similar items.
7. Isolate shaft-wall assemblies from building structure at locations indicated to prevent transfer of loading imposed by structural movement. Comply with details indicated on Drawings.

8. Seal gypsum board shaft-walls at perimeter of each section that abuts other work and at joints and penetrations within each section. Install acoustical sealant to withstand dislocation by air pressure differential between shaft and external spaces; comply with manufacturer’s instructions and ASTM C919.

9. Shaft Wall Framing: Comply with manufacturer’s installation instructions.
   a. Install studs at spacing required to meet performance requirements.

B. Metal Framing

1. Metal Framing General: Comply with ASTM C754 and manufacturer’s instructions, ASTM C754 and with ASTM C840 requirements that apply to framing installation.
   a. Install supplementary framing, blocking, and bracing at terminations in gypsum board assemblies to support fixtures, equipment services, heavy trim, grab bars, toilet accessories, furnishings, or similar construction. Comply with details indicated and with recommendations of gypsum board manufacturer or, if none available, with “Gypsum Construction Handbook” published by United States Gypsum Co.
   b. Isolate steel framing from building structure at locations indicated to prevent transfer of loading imposed by structural movement. Comply with details shown on Drawings.
      1) Where building structure abuts ceiling perimeter or penetrates ceiling.
      2) Where partition framing and wall furring abut structure except at floor.
         a) Provide slip- or cushioned-type joints as detailed to attain lateral support and avoid axial loading.
      3) Install elastomeric spray-applied sealant and mineral wool deck flute packing as required at deflection track in accordance with manufacturer’s instructions.
   c. Do not bridge building expansion and control joints with steel framing or furring members. Independently frame both sides of joints with framing or furring members as indicated.
   d. Provide anchorage bracing and support designed to meet structural seismic requirements of the Seattle Building Code.

2. Suspended Ceilings and Soffits:
   a. Suspend ceiling hangers from building structural members and as follows:
      1) Install hangers plumb and free from contact with insulation or other objects within ceiling plenum that are not part of supporting structural or ceiling suspension system. Splay hangers only where required to miss obstructions and offset resulting
horizontal forces by bracing, counter-splaying, or other equally effective means.

2) Where width of ducts and other construction within ceiling plenum produces hanger spacing that interfere with the location of hangers required to support standard suspension system members, install supplemental suspension members and hangers in form of trapezes or equivalent devices. Size supplemental suspension members and hangers to support ceiling loads within performance limits established by referenced standards and requirements of AHJ.

3) Secure wire hangers by looping and wire-tying, either directly to structures or to inserts, eyescrews, or other devices and fasteners that are secure and appropriate for substrate, and in a manner that will not cause them to deteriorate or otherwise fail due to age, corrosion, or elevated temperatures.

4) Secure flat, angle, channel, and rod hangers to structure, including intermediate framing members, by attaching to inserts, eyescrews, or other devices and fasteners that are secure and appropriate for structure as well as for type of hanger involved, and in a manner that will not cause them to deteriorate or fail due to age, corrosion, or elevated temperatures.

5) Do not support ceilings directly from permanent metal forms. Furnish cast-in-place hanger inserts that extend through forms.

6) Do not attach hangers to steel deck tabs.

7) Do not attach hangers to steel roof deck. Attach hangers to structural members.

8) Do not connect or suspend steel framing from ducts, pipes or conduit.

b. Sway-brace suspended steel framing with hangers used for support.

c. Install suspended steel framing components in sizes and at spacing indicated but not less than that required by the referenced steel framing installation standard.

1) Wire Hangers: 4 feet on center.

2) Carrying Channels (Main Runners): 1-1/2 inch, 4 feet on center.

3) Rigid Furring Channels (Furring Members): 16 inches on center.

d. Installation Tolerances: Install steel framing components for suspended ceilings so that cross-furring members or grid suspension members are level to within 1/8 inch in 12 feet as measured both lengthwise on each member and transversely between parallel members.

e. Wire-tie or clip furring members to main runners and to other structural supports as indicated.

f. Grid Suspension System: Attach perimeter wall track or angle where grid suspension system meets vertical surfaces. Mechanically join main
beam and cross-furring members to each other and butt-cut to fit into wall track.

g. Install bracing as required at exterior locations to resist wind uplift.

3. Framing for Walls and Partitions:

a. Install runners (tracks) at floors, ceilings, and structural walls and columns where gypsum board stud assemblies abut other construction.

b. Installation Tolerances: Install each steel framing and furring member so that fastening surfaces do not vary more than 1/8 inch from the plane formed by the faces of adjacent framing.

c. Extend partition framing full height to structural supports or substrates above suspended ceilings, except where partitions are indicated to terminate at suspended ceilings. Cut studs 1/2 inch short of full height. Continue framing over frames for doors and openings and frame around ducts penetrating partitions above ceiling to provide support for gypsum board.

1) For STC-rated and fire-resistive-rated partitions requiring partitions to extend to the underside of floor/roof slabs and decks or other continuous solid structural surfaces to obtain ratings, install framing around structural and other members extending below floor/roof slabs and decks, as needed, to support gypsum board closures needed to make partitions continuous from floor to underside of solid structure.

d. Terminate partition framing at suspended ceilings where indicated.

e. Install steel studs and furring in sizes and at spacing indicated but not less than that required by the referenced steel framing installation standard to comply with maximum deflection and minimum loading requirements specified:

f. Install steel studs so that flanges point in the same direction and so that leading edges or ends of each gypsum board can be attached to open (unsupported) edges of stud flanges first.

g. Frame door openings to comply with details indicated, with GA-219, and with applicable published recommendations of gypsum board manufacturer. Attach vertical studs at jambs with screws either directly to frames or to jamb anchor clips on door frames; install runner track section (for cripple studs) at head and secure to jamb studs.

1) Extend vertical jamb studs through suspended ceilings and attach to underside of floor or roof structure above.

h. Frame openings other than door openings to comply with details indicated or, if none indicated, in same manner as required for door openings. Install framing below sills of openings to match framing required above door heads.

4. Openings: Reinforce openings as required for weight of doors or operable panels, using not less than double studs at jambs.
5. Standard Wall Furring: Install at masonry walls scheduled to receive gypsum board, not more than 4 inches from floor and ceiling lines and abutting walls. Secure in place on alternate channel flanges at maximum 24 inches on center.
   a. Orientation: Horizontal.

6. Blocking: Install supplementary framing, and blocking to support fixtures, equipment services, heavy trim, grab bars, toilet accessories, furnishings, or similar construction.

3.04 GYPSUM BOARD INSTALLATION

A. Comply with ASTM C840 and GA-216. Install to minimize butt end joints, especially in highly visible locations.

1. Gypsum Soffit Board: Install perpendicular to framing, with staggered end joints over framing members or other solid backing.

2. Cementitious Backing Board: Install over steel framing members where indicated, in accordance with ANSI A108.11 and manufacturer's instructions. Curved Surfaces: Apply gypsum board to curved substrates in accordance with GA-226.

3. Moisture Protection: Treat cut edges and holes in moisture resistant gypsum board and exterior gypsum soffit board with sealant.

4. Install ceiling board panels across framing to minimize the number of abutting end joints and avoid abutting end joints in the central area of each ceiling. Stagger abutting end joints of adjacent panels not less than one framing member. Do not install water resistant gypsum backing board at ceiling locations.

5. Install wall/partition board panels to minimize the number of abutting end joints or avoid them entirely. Stagger abutting end joints not less than one framing member in alternate courses of board. At stairwells and other high walls, install panels horizontally with end abutting joints over studs and staggered.

6. Install gypsum panels with face side out. Do not install imperfect, damaged, or damp panels. Butt panels together for a light contact at edges and ends with not more than 1/16 inch of open space between panels. Do not force into place.

7. Locate both edge or end joints over supports, except in ceiling applications where intermediate supports or gypsum board back-blocking is provided behind end joints. Position adjoining panels so that tapered edges abut tapered edges, and field-cut edges abut field-cut edges and ends. Do not place tapered edges against cut edges or ends. Stagger vertical joints over different studs on opposite sides of partitions. Avoid joints at corners of framed openings where possible.

8. Attach gypsum panels to steel studs so that the leading edge or end of each panel is attached to open (unsupported) edges of stud flanges first.

9. Attach gypsum panels to framing provided at openings and cutouts.

10. Form control joints and expansion joints at locations indicated and as detailed, with space between edges of adjoining gypsum panels, as well as supporting framing behind gypsum panels.

11. Cover both faces, of steel stud partition framing with gypsum panels in concealed spaces (above ceilings), except in chase walls that are braced internally.
a. Except where concealed application is indicated or required for sound, fire, air, or smoke ratings, coverage may be accomplished with scraps of not less than 8 square feet in area.

b. Fit gypsum panels around ducts, pipes, and conduits.

12. Space fasteners in gypsum panels according to referenced gypsum board application and finishing standard and manufacturer's recommendations

13. Tolerances

a. Maximum Variation of Finished Gypsum Board Surface from True Flatness: 1/8 inch in 10 feet in any direction.

B. Gypsum Board Application Methods

1. Single-Layer Application: Install gypsum wallboard panels as follows:

a. On ceilings, apply gypsum panels prior to wall partition board application to the greatest extent possible and at right angles to framing, unless otherwise indicated. Provide firm bearing for all ends and edges.

b. On partitions/walls, apply gypsum panels vertically (parallel to framing), unless otherwise indicated, and provide panel lengths that will minimize end joints. Provide firm bearing for all ends and edges.

c. On Z-furring members, apply gypsum panels vertically (parallel to framing) with no end joints. Locate edge joints over furring members.

2. Double-Layer Application: Install same gypsum wallboard as scheduled for base layers and for face layers.

a. On ceilings, apply base layer prior to applying base layer on walls/partitions; apply face layers in same sequence. Offset face-layer joints at least 10 inches from parallel base-layer joints. Apply base layers at right angles to framing members unless otherwise indicated.

b. On partitions/walls, apply base layers and face layers vertically (parallel to framing) with joints of base layers located over stud or furring member and face layer joints offset at least one stud or furring member with base layer joints. Stagger joints on opposite sides of partitions.

c. On Z-furring members, apply base layer vertically (parallel to framing) and face layer either vertically (parallel to framing) or horizontally (perpendicular to framing) with vertical joints offset at least one furring member. Locate edge joints of base layer over furring members.

3. Wall Tile Substrates: For substrates indicated to receive thin-set ceramic tile and similar rigid applied wall finishes, comply with the following:

a. Install tile backer board to comply with ANSI A108.11.

4. Single-Layer Fastening Methods: Apply gypsum panels to supports as follows:

a. Fasten with screws.

5. Double-Layer Fastening Methods: Apply base layer of gypsum panels and face layer to base layer as follows:
a. Fasten both base layers and face layers separately to supports with screws, or as follows.

b. Fasten base layers with screws and face layer with adhesive and supplementary fasteners.

C. Trim and Accessories

1. Control Joints: Place control joints consistent with lines of building spaces and as indicated.

   a. Not more than 30 feet apart on walls and ceilings over 50 feet long.

   b. At exterior soffits, not more than 30 feet apart in both directions.

2. Corner Beads: Install at external corners, using longest practical lengths.

3. Edge Trim: Install at locations where gypsum board abuts dissimilar materials. Install edge trim where edge of gypsum panels would otherwise be exposed or semi-exposed. Provide edge trim type with face flange formed to receive joint compound except where other types are indicated.

   a. Install LC-bead where gypsum panels are tightly abutted to other construction and back flange can be attached to framing or supporting substrate.

   b. Install L-bead where edge trims can only be installed after gypsum panels are installed

D. Joint Treatment

1. General: Apply joint treatment at gypsum board joints (both directions); flanges of corner bead, edge trim, and control joints; penetrations; fastener heads, surface defects, and elsewhere as required to prepare gypsum board surfaces for decoration and levels of gypsum board finish indicated.

   a. Pre-fill open joints, rounded or beveled edges, and damaged areas using setting-type joint compound.

   b. Apply joint tape over gypsum board joints except those with trim accessories having concealed face flanges not requiring taping to prevent cracks from developing in joint treatment at flange edges.

   c. Apply joint tape over gypsum board joints and to trim accessories with concealed face flanges as recommended by trim accessory manufacturer and as required to prevent cracks from developing in joint compound at flange edges.

3.05 TOLERANCES

A. Maximum Variation of Finished Gypsum Board Surface from True Flatness: 1/8 inch in 10 feet in any direction.

3.06 FIELD QUALITY CONTROL

A. Ceiling Framing Observation: Before Contractor installs gypsum board ceilings, coordinate an above-ceiling observation with the Resident Engineer and report deficiencies in the Work observed. Do not proceed with installation of gypsum board to ceiling support framing until deficiencies have been corrected.
1. Notify Resident Engineer 7 days in advance of date and time when Work, or part of Work, will be ready for ceiling framing observation.

3.07 CLEANING

A. Promptly remove any residual joint compound from adjacent surfaces.

3.08 PROTECTION

A. Provide final protection and maintain conditions, in a manner suitable to Installer that ensures gypsum board assemblies remain without damage or deterioration at time of Completion.

3.09 SCHEDULE

A. Finish Levels

1. Finish gypsum board in scheduled areas in accordance with levels defined in ASTM C840 and as scheduled below.

2. Level 1: Above finished ceilings concealed from view, for ceiling plenum areas, and where indicated, unless a higher level of finish is required for fire-resistive-rated assemblies and/or sound-rated assemblies.

3. Level 2: Utility areas and where cementitious backing board panels form substrates for tiling, and where indicated.

4. Level 3: Standard finish level unless otherwise noted.

5. Level 4: Not used. (To be used at buildings in non-Station application)

6. Level 5: Not used.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing and applying high performance coating systems in the shop and field on certain items and types of work, as scheduled; including surface preparation, primer coats, intermediate coats, finish coats, field touch-up, and related thinners and associated materials. Coatings used in the systems specified in this Section include:

1. HPC-1: High-Performance Coating for Exposed Concrete and Concrete Unit Masonry: High-build epoxy primer and finish coats.

2. HPC-2: High-Performance Coating for Exposed Primed Structural and Miscellaneous Steel: High solids zinc-rich epoxy/acrylic urethane.


4. HPC-4: High-Performance Coating for Exposed Aluminum Metal: Factory High-performance Fluoropolymer (Polyvinylidene Fluoride or PVDF) coatings with clear top coat.

5. HPC-5: High-Performance Coating to Separate Dissimilar Metals: Coal Tar Epoxy Coating.

6. HPC-6: High-Performance Zinc-rich Primer.

7. Other High-Performance Coatings as described in this Section.

1.02 REFERENCES

A. This Section incorporates by reference the current versions of the following documents.

1. American Architectural Manufacturers Association (AAMA)
   a. AAMA 605.2 Voluntary Specification for High Performance Organic Coatings on Architectural Extrusions and Panels

2. American Association of State Highway and Transportation Officials (AASHTO)
   a. AASHTO M 298 Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel

3. ASTM International
   b. ASTM C1028 Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method
c. ASTM D523 – Standard Test Method for Specular Gloss

d. ASTM D822/D822M – Standard Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings

e. ASTM D968 – Standard Test Methods for Abrasion Resistance Organic Coatings by Falling Abrasive

f. ASTM D2244 – Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates

g. ASTM D3359 – Standard Test Methods for Measuring Adhesion by Tape Test

h. ASTM D3361/D3361M – Standard Practice for Unfiltered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings

i. ASTM D4214 – Standard Test Methods for Evaluating the Degree of Chalking of Exterior Paint Films

4. MPI - Master Painters Institute Architectural Painting Specification Manual: For application procedures

5. NAAMM (National Association of Architectural Metal Manufacturers)
   a. AMP 500-06 "Metal Finishes Manual for Architectural Metal Products"

6. Society for Protective Coatings (SSPC)
   a. SSPC-SP 1 Solvent Cleaning
   b. SSPC-SP 2 Hand Tool Cleaning
   c. SSPC-SP 3 Power Tool Cleaning.
   d. SSPC SP 6 Commercial Blast Cleaning
   e. SSPC-SP 10 Near-White Blast Cleaning
   f. SSPC-SP 11 Power Tool Cleaning to Bare Metal.
   g. SSPC-SP COM Surface Preparation Commentary Steel and Concrete Substrates
   h. SSPC-Paint 16 Coal Tar Epoxy-Polyamide Black (or Dark Red) Coating

1.03 SUBMITTALS

A. Submit complete high performance coating system submittals for all iron and steel work prior to or in conjunction with the steel shop drawings to assure compatibility between steel shop primer and intermediate and finish high performance coatings. This submittal will not be considered complete and acceptable if either product is not compatible with each other.

B. Product Data: Submit data on coating system, including coating manufacturer's most current technical data sheets on each product showing application procedures, coverage rates and dry mil thicknesses; include additive requirements for Low-Temperature application.

C. Samples: Using approved materials, submit samples of finish coat, illustrating colors, gloss and finishes selected. For each separate color, prepare sample with exposed portions of
each successive coat, on required number of 8-inch by 10-inch card stock draw-downs and one 12 inch by 12 inch sample of each color on substrate material matching work to be finished, or sheet metal which shall be representative of the in-place steel substrates. Label samples with color number, name and date. Provide samples of each color as indicated using complete coating system by application method proposed for the finish Work. Submit additional samples if required for approval. Provide samples of both the thermo-curing and air drying PVDF coatings.

D. Mockup for HPC-2, In Place: Provide a full-size, 10 foot minimum height mockup of an exterior structural column to serve as the standard for the work of this Section. Comply with the following:

1. Application of materials shall be performed using same materials, methods, and procedures to be used throughout the balance of the Work.

2. Mock up shall incorporate specified surface preparation, including field touch-up of welds and abrasions with specified primer, tie/intermediate, as required, and finish top coatings, including Low-Temperature additive as proposed in the finish Work, as applicable.

3. Resident Engineer will direct location and extent of exterior structural steel column to be coated.

4. Notify Resident Engineer in advance of dates and times when mockup shall be completed.

5. Resident Engineer’s review and approval of mock up shall include, but not necessarily be limited to:
   
   a. Uniformity in color, gloss and hide characteristics of high performance finish

   b. Applicator’s ability to provide continuous film of uniform thickness, free from surface imperfections which show evidence of poor workmanship or the coating’s inability to be applied in the proposed application method

6. Obtain Resident Engineer’s approval of mockup before starting High-Performance Coatings.

7. If the Resident Engineer determines that mockup does not meet requirements for accepted appearance, repaint using revised methods.

8. Approved mockup may become part of the completed Work, if maintained undisturbed at time of Acceptance.

E. Manufacturer’s Installation Instructions: Indicate special surface preparation procedures and perimeter conditions requiring special attention.

F. Manufacturer’s Certificate: Certify that products meet or exceed specified requirements.

G. Certification:

1. By manufacturer that all coatings do not contain any of the prohibited chemical specified; GreenSeal GS-11 shall constitute acceptable certification or per LEED certification VOC limit requirements, as applicable.

H. Applicators Quality Control procedures for shop and field painting and coating.

I. Manufacturers and applicators qualifications, per Article 1.06 herein: For all coating systems.
J. Field Quality Control Reports

K. Maintenance Data: Submit data on cleaning, touch-up, and repair of painted and coated surfaces.

L. Warranties: Provide each warranty listed

1.04 MAINTENANCE MATERIAL SUBMITTALS

A. Color Mix Formula: In lieu of extra stock materials, submit a single submittal including the following.
   1. Mix formula for each color, in measured increments of 48ths of an ounce.
   2. Paint manufacturer, color, and identification number
   3. Manufacturer of base
   4. Five color chips of each color
   5. Location list of where each color was applied

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications: Company specializing in manufacturing the products specified in this Section with minimum three years documented experience.

B. Applicator Qualifications: Company specializing in performing the Work of this section with 3 years minimum documented experience; has completed paint applications similar in magnitude to that indicated for this Project; and is acceptable to the manufacturer for all coating systems. Only skilled painters shall be used with 5 years minimum painting experience and 3 years minimum experience using similar opaque aesthetic coating products by similar application methods.

C. Single Source: The shop-applied primer applied in related sections, and field-applied intermediate, finish color, and top coatings, which constitute the High-Performance Coating system, shall be manufactured by the same manufacturer to ensure undivided responsibility.

D. Pre-Application Conference: Schedule a Readiness Review Meeting to review the work. Conference shall be attended by Applicator, authorized representative of coating manufacturer, Resident Engineer, and other representatives directly concerned with the performance of work. The following major considerations shall be reviewed at conference:
   1. Inspect shop-primed steel for undercutting or all other signs of failure.
   2. Inspect concrete surfaces for contamination or other conditions detrimental to coating application.
   3. Discuss scaffolding and staging requirements.
   4. Review surface preparation and cleaning requirements.
   5. Review schedule, sequencing, and time lapse between each separate coat. Discuss re-coat time limits as established by manufacturer.
   6. Review methods and materials which are to be used for protection of surrounding buildings and to contain over-spray and falling paint spatter.
7. Discuss environmental conditions, including temperature, relative humidity, wind conditions and sun exposure under which materials may not be applied.

8. Review quality control procedures, which will be employed in determining the daily environmental conditions, containment, and disposal; include a list of those instruments, which will be used.

9. Review forecasted weather conditions, and procedures for coping with unfavorable conditions: tenting, heat, mechanical ventilation, etc.

1.06 PROJECT CONDITIONS

A. Environmental Requirements: During field application or field touch-up comply with the following:

1. Air temperature and substrate temperature and relative humidity shall be within the manufacturer’s established limits. Field apply coating only when the temperature of the surfaces to be coated and surrounding air temperature are above 55 degrees Fahrenheit as verified and documented, and are expected to remain so until the coating has fully dried or cured, unless other temperature limits are permitted by manufacturer’s printed instructions.

2. Do not apply coatings when the following conditions exist, unless requirements of paint manufacturer are more restrictive.
   a. If surface and ambient temperature is above 90 degrees Fahrenheit, or below 55 degrees Fahrenheit.
   b. Do not apply coatings in snow, rain, fog or mist or when the relative humidity exceeds 85 percent; or at temperatures less than 5 degrees Fahrenheit above the dew point; or to damp or wet surfaces, during inclement weather, or during excessively windy weather.

3. Allow wet or damp surfaces to dry thoroughly and attain the temperature and condition specified before proceeding with or continuing coating applications.

4. Work may continue during inclement weather only if areas and surfaces to be coated are enclosed and the temperature and humidity within the area can be maintained with limits specified as above and per the manufacturer during application and curing periods.

5. Field-applied coatings which, in the judgment of the Resident Engineer, are applied under improper conditions or which do not meet quality control standards shall be appropriately removed and reapplied at no additional cost to Sound Transit.

6. Provide lighting level of 80 foot candles measured mid-height at substrate surface.

7. Restrict traffic from area where coating is being applied or is curing.

8. Protection: Protect surrounding areas, buildings, and cars against damage due to cleaning operations and from paint application. Method of protection is at Contractor's option, and shall be reviewed with the Resident Engineer prior to starting the Work. Sound Transit will not be responsible for Contractor's selection or method of protection or failure to protect. Protective coverings shall be secured against wind and shall be vented to prevent collection of moisture on covered surfaces.

9. Provide "wet paint" signs as required to protect newly painted surfaces.
10. Any portions of the surrounding areas, which are damaged as a result of Contractor's activities, shall be restored, refinished, and replaced at Contractor's expense.

1.07 DELIVERY, STORAGE & HANDLING

A. Deliver materials to site in sealed, original, labeled containers bearing manufacturer's name, type of material, brand name, color designation, and instructions for mixing and thinning.

B. Store materials when not in actual use in a place specifically assigned for that purpose which is dry and out of direct sunlight. Store materials in a manner so as not to exceed the manufacturer's temperature limitations.

1.08 WARRANTY

A. The warranty for each coating system shall be countersigned by both the coatings manufacturer for materials, and by the applicator for workmanship.

B. Correct Defective Work within a 5 year period.

C. Warranty: Include coverage for bond to substrate.

PART 2 - PRODUCTS

2.01 PERFORMANCE REQUIREMENTS

A. Performance Requirements for HPC-1, HPC-2, HPC-3 and HPC-4:

1. Provide coating systems that meet the following minimum performance criteria, unless more stringent criteria are specified:

   a. Abrasion resistance: 65, when tested in accordance with ASTM D968.

   b. Adhesion: No pick-off, when tested in accordance with ASTM D3359 Cross Cut Tape Test.

   c. Salt spray resistance: No field blisters, Max 1/32 inch creepage on scribe, when tested in accordance with ASTM B117 five percent Salt-Fog, 1000 hours.

   d. Chalking: Maximum rating 8 for colors, 6 for whites, in accordance with ASTM D659.

   e. Accelerated Weathering:

      1) 60/60 cycle, 500 cycles, in accordance with ASTM D3361/D3361M, with chalk rating between 9 and 10 in accordance with ASTM D4214, and Color Change no more than 10 delta E units in accordance with ASTM D2244, and Gloss Retention of min. 60 percent in accordance with ASTM D523.

      2) 5000 hours, in accordance with ASTM D822/D822M, with chalk rating of 8 to 10 in accordance with ASTM D4214, and color change of less than 5 delta E units in accordance with ASTM D2244, and 60 percent gloss retention in accordance with ASTM D523.
2.02 MANUFACTURERS

A. Subject to compliance with requirements of Article 1.06 herein.

B. Paint systems listed are Basis of Design. Other manufacturer’s systems are acceptable if approved equal.

2.03 MATERIALS

A. General: Provide complete multi-coat systems formulated and recommended by manufacturer for the applications indicated, in the thicknesses indicated. Number of coats specified does not include filler coats.

B. Maximum volatile organic compound (VOC) content: As limited by applicable regulations of Authority Having Jurisdiction and the Sustainability Checklist, whichever is more restrictive.

C. Colors: As indicated in the Contract Documents

D. Sheen: Finish coats shall have semi-gloss sheen.

E. Coatings: Numbers of Coats listed are minimums. Apply coats as required to achieve specified dry film thicknesses (dft).

F. Thinners: Type as supplied or approved by the coating manufacturer. Use thinner only when recommended by the coating manufacturer, and then only in a quantity as indicated on the label.

G. HPC-1: High-Performance Coating for Exposed Interior and Exterior Concrete and Concrete Unit Masonry: High-build epoxy primer and finish coat.

1. Basis-of-Design Manufacturer: Tnemec Coatings Co.
   a. Concrete, Opaque, 2 Coats min.:
      a) First Coat: Tneme-Crete WB, Series 180 acrylic coating, by Tnemec Company, Inc. Apply to 5-6 mil dry film thickness.

2. Concrete Unit Masonry, Opaque, 3 Coats min.:
   b. Second Coat: Tnemec Series 156 "Enviro-crete." Apply to 5-6 mil dry film thickness.
   c. Third Coat: Tnemec Series 156 "Enviro-crete." Apply to 5-6 mil dry film thickness.


1. Type: Zinc Rich Primer/HB Epoxy/Acrylic Polyurethane

2. Number of Coats: 3 Coats Min.
3. Total Dry Film Thickness: 11-15 mils dft
4. Surface Preparation: SSPC-SP 10
   a. DeVoe Cathacoat 313 or 302H
   b. Tnemec Series 90-97 Tneme-Zinc or 394 PerimiPrime
6. Intermediate: High-Build Epoxy, 4 mils dft
   a. DeVoe Devran 261QC
   b. Tnemec Series 27 F.C. Typoxy
7. Finish: Aliphatic Acrylic Polyurethane, 4 mils dft
   a. DeVoe Devthane 349QC
   b. Tnemec Endura-Shield Series 750 UVX

I. HPC-3: High-Performance Coating for Exposed Galvanized Structural Steel: High-build aliphatic acrylic polyurethane. Sherwin Williams or approved equal.
1. Type: HD Galvanized/Recoatable Epoxy/Hi-Solids Polyurethane, 3 Coats Min. over galvanizing
2. Total Dry Film Thickness: 11 – 17 mils dft over galvanizing
3. Hot-Dip Galvanizing: in accordance with Section 05 05 13, Shop-Applied Coatings for Metal.
4. Coating Surface Preparation: SSPC-SP 1
5. Primer: 1 Coat min, Recoatable Epoxy, 3-5 mils dft
   a. Corothane I Ironox B by Sherwin Williams
6. Finish: 2 Coats min., Hi-Solids Aliphatic Acrylic Polyurethane, total 4-6 mils dft
   a. Corothane I Aliphatic by Sherwin Williams. Apply to 2-3 mils dft per coat

J. HPC-4: High-Performance Coating for Exposed Metal: Shop/Factory/Field-applied high-performance PVDF coatings as follows:
1. Shop / Factory-Applied Thermocured PVDF Resin Based Coating on prepared substrate: A high performance thermoplastic, organic coating containing a minimum of 70 percent PVDF by weight in the resin system.
2. PVDF Coatings: Apply 3-coat coil coating consisting of 1 coat inhibitive primer, 1 coat PVDF color coating, and 1 coat PVDF clear topcoat.
3. Clean the substrate metal in accordance with manufacturer’s recommendations in the handling and application of the specified product and all compatible primers.
4. The substrate shall be primed in accordance with the manufacturer’s recommendations for the substrate material, including chemical conversion coating, if required. Minimum thickness as recommended by the manufacturer for the primer and substrate.
5. Apply and oven-bake the color coat(s) to minimum thickness of 0.8 mil per coat, in accordance with manufacturer's written procedures.

6. Apply and oven-bake clear top coat to minimum thickness of 0.4 mil, in accordance with manufacturer's written procedures.

7. Air-Drying PVDF Resin Based Touch-up Coating: A high performance thermoplastic, organic coating containing a minimum of 70 percent PVDF by weight in the resin system to be used for maintenance and touch-up applications in field.

8. Apply as touch-up application to shop / factory-applied PVDF finishes.

K. HPC-5: High-Performance Coating to Separate Dissimilar Metals: Coal Tar Epoxy Coating:

1. Two coats, Min. high-build, two-part, SSPC-Paint 16 at locations detailed or where recommended by envelope system manufacturers. Manufacturer listed dry film thicknesses are to be used as a min. dft for the system.

L. HPC-6: High-Performance Primers: As recommended by coating manufacturer for specific substrate, unless otherwise specified.

1. Type A: Zinc-Rich Primer
   a. Number of Coats: 1 Coat min.
   b. Total Dry Film Thickness: 3 mils dry film thickness
   c. Surface Preparation: SSPC-SP 10
   d. Primer: Zinc-Rich Primer, 3 mils dft

2.04 HIGH-PERFORMANCE STRUCTURAL STEEL COATINGS AT CONNECTIONS

A. Faying surfaces and interiors of bolt holes for bolted structural steel connection in steel that is coated under this Section shall receive only primer prior to erection. Primer shall meet or exceed slip coefficient requirements for fully coated connections from AISC for buildings and AASHTO for bridges and tunnels.

1. Type: Urethane Primer

2. 63 percent solids by volume

3. 82 percent zinc in cured film

4. 23 pounds per gallon

5. VOC compliance

6. Lead free

7. Provides Class B faying surface of slip-critical joints in accordance with ASTM C1028

B. Bolts (except Tension control bolts) and other fasteners for bolted structural steel connections in steel that are coated under this Section shall be furnished with mechanical galvanizing in accordance with AASHTO M 298, Class 55, Type 1.
PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify existing conditions before starting work.

B. Verify that substrate surfaces are ready to receive work as instructed by the coating manufacturer. Obtain and follow manufacturer's instructions for examination and testing of substrates. Coating applicator shall inspect the primed surfaces. Should inspection reveal any signs of primer failure, corrosion on substrate, conditions detrimental to the performance of this work, or window of recoat time has been exceeded, such failure and/or conditions shall be immediately reported to the Contractor. It shall be the Contractor's responsibility to see that the surfaces are put into acceptable condition.

C. Coating applicator shall be required to clean surfaces as hereinafter specified to remove all dust, dirt, and other surface contamination. Commencement of work constitutes acceptance of surfaces and conditions.

D. Cementitious Substrates: Do not begin application until substrate has cured 28 days minimum and measured moisture content is not greater than 16 percent.

E. Masonry: Verify masonry joints are struck smooth and mortar is fully cured.

3.02 SURFACE PREPARATION

A. General:

1. Surface preparations and cleaning procedures shall be in strict accordance with the instructions and specifications of the coating manufacturer and with the requirements herein.

2. Remove substances that would bleed through finished coatings. If not removable, seal surface with shellac.

3. Remove finish hardware, fixture covers, and accessories and store. Protect items that are not removable.

4. Cleaning and Touch-Up for abraded areas in field erection and fabrication shall be completed in conformance with manufacturer's recommendations.

B. Cleaning of Shop-Primed Surfaces: Thoroughly clean steel surfaces to remove all rust, scale, dirt, grease, and other foreign material from surfaces, connections, bolts, nuts, and areas around welds surfact oil and other contaminants. Clean surfaces using power washing equipment and non-phosphate, biodegradable chemical cleaner.

1. Field test on a small area to determine the most effective method (type of nozzle employed, operating pressure, and distance of nozzle from surface) to achieve maximum cleaning results without damaging or etching the existing primer.

2. After washing with cleaner, power wash surfaces thoroughly with fresh water under high pressure to remove all traces of the chemical cleaner.

C. Ferrous Metal:

1. Solvent clean.

2. Remove loose rust, loose mill scale, and other foreign substances hand tools according to SSPC-SP 2 or power tools according to SSPC-SP 3.
3. Protect adjacent surfaces and materials not receiving coating from overspray; mask if necessary to provide adequate protection. Repair damage.

D. Cleaning For Galvanized/Galvannealed Surfaces: Thoroughly clean steel surfaces to remove surface oils and other contaminants in accordance with SSPC-SP 1. Follow manufacturer's additional requirements for the removal of soluble salts as may be required in accordance with SSPC-SP COM.

3.03 APPLICATION OF COATINGS

A. Mixing: Mix coating materials in accordance with the manufacturer's instructions and directions. Mix often enough during application to keep the coatings uniform and to ensure complete dispersion of pigment and a uniform composition.

1. Prepare multiple component coatings using all of the contents of the container for each component as packaged by the manufacturer. Mixing of partial kits will not be permitted. Multiple component coatings that have been mixed shall not be used beyond their pot life. Only the components specified and furnished by the manufacturer, including thinner if required, shall be mixed.

2. Intermediate coat primer may be thinned for spray applications, in accordance with manufacturer's most current printed technical data sheet.

3. Accelerator may be used in intermediate coat and finish coat to enable faster cure time during Low Temperature applications when approved by Resident Engineer; use accelerator type as supplied by the manufacturer, and then only in a quantity as indicated on manufacturer's most current printed technical data sheet.

B. Application Method: Apply both intermediate coat and finish coat in a full application method, in accordance with the manufacturer's most current printed technical data sheet. Use techniques best suited for substrate and type of material being applied.

1. Spray Application: Spray painting shall be accomplished with airless spray equipment or conventional spray equipment; pressure settings, application technique, spray tip, mesh filter screens, and mesh tip strainer shall be as recommended by the coating manufacturer for each separate system.

2. Apply each coat within the manufacturer's recommended recoating time periods. Should time period for application be exceeded, Contractor shall then follow manufacturer's most current printed technical data sheet which may include an additional prime coat or scarification at no additional cost to Sound Transit.

3. When applying paint, overlap each pass 50 percent followed by cross-hatch pattern.

4. During application of each coating, remove all foreign material from applicators (brush, rollers or pads) and protect wet surfaces from contamination of air borne dust and debris.

C. Apply each coat of paint as a continuous film of uniform thickness, free from holidays, sags, crawls, pinholes, blisters, unevenness in color, or other evidence of poor workmanship. Repaint thin spots or areas missed in the application, and allow to dry before applying next coat of paint. Give special attention to ensure that surfaces, such as edges, corners, crevices, welds and exposed fasteners receive a dry film thickness equivalent to that of flat surfaces.

1. Coverage for paint material is specified as the total minimum dry film thickness in mils.
D. Maintain Cure Times: Provide full cure times necessary to resist direct contact with moisture. Comply with manufacturer’s requirements and Contractor’s approved quality control procedures based on actual site conditions.

E. Priming

1. Apply primer to all surfaces, unless specifically not required by coating manufacturer. Apply in accordance with coating manufacturer’s instructions.

2. Concrete Unit Masonry: Apply masonry filler to thickness required to provide a smooth, monolithic, pinhole-free film surface with a minimum thickness of 30 mils.

F. Intermediate Coats:

1. Repair, and recoat any blisters, runs or sags in primer coat prior to application of intermediate coats.

2. Intermediate coats shall fully cover and hide primer coat.

G. Finish Coats:

1. Repair, and recoat any blisters, runs or sags in previous coats prior to application of finish coats.

2. Finish coats shall fully cover and hide intermediate coat.

3.04 FIELD QUALITY CONTROL

A. Dry Film Thickness Testing: Contractor shall engage the services of a qualified testing and inspecting agency to inspect and test coatings for dry film thickness.

B. Contractor shall touch-up and restore coated surfaces damaged by testing.

C. If test results show that dry film thickness of applied coating does not comply with coating manufacturer’s written recommendations or these specifications, Contractor shall repair areas that does not meet quality standards to provide dry film thickness that complies with coating manufacturer’s written recommendations and pay for re-testing.

3.05 PROTECTION AND TOUCH-UP WORK:

A. General: Before final acceptance of the Work, Contractor shall repair or re-finish coated surfaces which have been damaged at no additional cost.

B. Areas of chipped, peeled, or abraded coatings shall be hand or power sanded, feathering the edges. Prime and finish coat the areas using the same material as originally scheduled. Depending on the extent of repair and its appearance, an overall finish coat to a natural break point may be required by the Resident Engineer to achieve uniform appearance.

C. Field Repair of Zinc/Epoxy/Urethane Paint Systems:

1. Where damage is limited to the epoxy or urethane coatings, use hand tool cleaning in accordance with SSPC-SP-2 or power tool cleaning, in accordance with SSPC-SP-3, to visibly damaged areas. Feather edges by mechanical means. Spot prime with the epoxy and topcoat with the specified polyurethane.

2. For minor scratches to the polyurethane top coat, clean and scuff sand the damaged area and apply the polyurethane in accordance with manufacturer’s recommendations.
3. Scratches, gouges, and other damaged areas where the substrate is exposed, spot field blast in accordance with SSPC-SP 6. Spot prime with organic zinc, followed by epoxy and urethane in accordance with Contract Specifications.

4. Solvent clean in accordance with SSPC-SP 1.

D. Field Repair of Factory-Applied PVDF Coating Systems:
   1. Apply approved air-drying PVDF or other approved touch-up coatings in accordance with manufacturer's instructions, and AAMA 605.2 to thicknesses specified.
   2. For minor scratches to the PVDF top coat, clean and scuff sand the damaged area and apply the air-drying PVDF coating in accordance with manufacturer’s recommendations.
   3. Apply in uniform thickness coats, without runs, drips, pinholes, brush marks, or variations in color, texture, or finish. Finish edges, crevices, corners, and other changes in dimension with full coating thickness.
   4. Color and gloss of touch-up coating shall match exactly the color and gloss of the shop-applied coatings.
   5. Apply PVDF touch-up coating to achieve a minimum thickness of 1.2 mil, including prime coat.

E. Coat connectors and disturbed surfaces to match adjacent surfaces. Field touchup work shall use the same sequence and thickness of coatings as specified for the original work. Touchup application efforts shall be done in accordance with the recommendations of the coating manufacturer, subject to acceptability to the Resident Engineer.

F. Coated assemblies shall be adequately protected from handling and shipping damage with the use of padded slings, dunnage, separators, tie downs, or other protective devices and methods. Use of bare cables is prohibited.

G. Protect work of this and other trades, whether to be coated or not, against damage from coatings and coating operations. Correct damage by cleaning, repairing, replacing, or recoating as acceptable to the Resident Engineer. Leave affected surfaces in undamaged condition. Touchup areas shall blend with finish coats. Additional touchup or an additional finish coat shall be required if there are visual imperfections, due to touchup work, as determined by the Resident Engineer, when viewed from a distance of 10 feet.

H. Continue protection, repair procedures, and touchup procedures as necessary so that coatings will be in an undamaged condition at the time of Acceptance.

3.06 CLEANING

A. General: During the progress of the work, remove from the project all discarded paint materials, rubbish, cans and rags. Leave premises clean and in orderly condition.

B. Collect waste material which may constitute a fire hazard, place in closed metal containers, and remove daily from site.

C. Clean surfaces immediately of overspray, splatter, and excess material.

D. After coating has cured, clean and replace finish hardware, fixtures, and fittings previously removed.
E. Cleaning: Upon completion of painting work, clean, restore, or replace, to the satisfaction of the Resident Engineer and at no expense to Sound Transit, all surfaces which have been damaged or surfaces which have been splattered.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:
   1. Regulatory and Facility signage for identification and instructions as required by the Authority having Jurisdiction (AHJ), installed as complete integrated system from a single manufacturer.

B. Types of signs required by this work include, but are not limited to:
   1. Exit Signs: To identify exits and exit access doors, and including under Related Sections.
   2. Stairs, Stairway Landings: To identify access, stair number, floor number and existence or absence of roof access.
   3. Elevator Signs: Emergency signs at each landing above ground floor to indicate exiting by stairs.
   4. Elevator Machine Room Sign: To indicate room is for authorized personnel use only, (WAC 296-96).
   5. Room Signs: Code and AHJ required identification signs.
   6. Accessibility Signage: To indicate accessible parking stalls, areas of rescue assistance, loading zones, toilet facilities, and directional signage to accessible facilities.
   7. Posting Maximum Room (Occupancy) Capacity: Provide room capacity sign for assembly rooms and individual spaces as indicated.
   8. Posting Maximum Live Loads: Provide loading capacity sign for room as required by the AHJ.

C. All sign copy shall be as required by the various codes involved.

D. Types of room required signs shall be as listed in the SIGN SCHEDULE located in the drawings.

E. ST Customer Signage and Systems Operational Signage is not included in this Section.

1.02 REFERENCES

A. Governing Codes:
   1. International Code Council, Inc. (ICC), Codes adopted by AHJ’s and associated codes, including State of Washington amendments, as applicable. See Drawings for current code version.
   2. Americans with Disabilities Act (ADA), ICC A117.1

1.03 SUBMITTALS

A. Submittals Required: The Contractor shall submit for review, before fabrication and after approval by the applicable code authorities, the following items for each type of sign to be provided in the Project:

1. Product Data: Manufacturer's information relating to the materials, finishes, and fasteners used in each type of sign.

2. Shop Drawings: Show type, size, color and thickness of typography, symbols, wording and attachment proposed for each type of sign.

3. Product Schedule: Include location plan showing the exact location for all signs being provided.

B. Warranty

1.04 QUALITY ASSURANCE

A. Installer Qualifications: An authorized representative of signage manufacturer for installation and maintenance of units required for this Project.

B. Source Limitations: Obtain each sign type through one source from a single manufacturer.

C. Regulatory Requirements: Comply with the Americans with Disabilities Act (ADA) and code provisions as adopted by authorities having jurisdiction.

1.05 COORDINATION

A. For signs supported by or anchored to permanent construction, advise installers of anchorage devices about specific requirements for placement of anchorage devices and similar items to be used for attaching signs.

1. For signs supported by or anchored to permanent construction, furnish templates for installation of anchorage devices.

B. Coordinate installation with adjacent finish materials in manner not to damage adjacent surfaces.

1.06 DELIVERY, STORAGE AND HANDLING

A. General: Comply with requirements of Section 01 60 00 – Product Requirements.

B. Handle signage in careful manner to prevent damage or marring of sign surfaces or adjacent finishes.

1.07 WARRANTY

A. Manufacturer's Warranty: Provide (5) five year limited warranty covering coating degradation, chalking, fading and delamination.

PART 2 - PRODUCTS

2.01 MANUFACTURER/FABRICATORS

A. Signage Manufacturers/Fabricators:

1. ASI
2. Fast Signs
3. Tube Art
4. Or approved equal

2.02  TYPICAL SIGNS

A. General: All materials shall be new and free from defects upon completion of the Contractor's work. All material shall be the products of manufacturers or suppliers of established good reputations regularly engaged in the furnishing of such materials. All of the Contractor's work shall be performed with the highest degree of skill and completed in accordance with the Contract Documents.

B. Signs Description:

1. Material: Integral colored high impact UV resistant, colorfast, cast acrylic, nominal 1/8 inch thick with square corner and edges.
2. Type: Unframed
3. Mounting: Wall or vertical surface as follows:
   a. Interior: Double sided vinyl tape.
   b. Exterior: Liquid adhesive as recommended by manufacturer, or mechanical fasteners as approved.
4. Copy Process: Tactile and Braille; photo-etched plastic and laminated to the insert face in one piece. Individually applied characters and Braille strips are expressly disallowed.
5. Copy and Color: Black, Blue, Red or Yellow as shown in 3.03 SIGNAGE SIGNTYPES.
6. Nominal Size: 8 inches by 10 inches, or as noted.

2.03  TYPOGRAPHY

A. Typography shall comply with code requirements. All lettering shall be executed in such a manner that all edges and corners of the letter forms are correctly spaced, true, clean, and photographically precise and shall accurately reproduce the letter form.

B. Type face shall be Humanist 777 Bold Condensed, unless otherwise noted, upper and lower case, unless otherwise required by code.

2. Color: Refer to 3.03 SIGNAGE SIGN TYPES for specific letter colors on backgrounds.
   a. White letters on Black background.
   b. Black letters on Yellow background.
   c. White letters on Red background.
   d. White letters on Blue background
   e. Red letters on yellow background, unless otherwise indicated.


2.04  PAINT COLORS:

1. Yellow: P4 MP31456
2. Blue: ADA Blue MP00366
3. Red: P3 MP00643
4. Black: Black
5. White: White

2.05 TACTILE (ADA) AND NON-TACTILE PLAQUE SIGNS INTERIOR APPLICATIONS

A. Tactile Signs: Faces shall consist of minimum 5/8 inch text in all caps. Text shall be raised a minimum of 1/32 inch above the surface of the sign panel. Grade 2 Braille shall be provided in a minimum dot height of .025 inch with inset round glass beads. Braille shall be separated 3/8 inch (9.5 mm) minimum from any other tactile characters. Adhesive-fixed characters are not acceptable.

B. Cleanability: Signs shall be cleanable with soap detergents and other similar non-abrasive cleaners without damage to the sign surface. Contractor shall provide complete cleaning instructions.

C. Mounting: Use foam tape in all interior areas.

PART 3 - EXECUTION

3.01 INSTALLATION, GENERAL

A. Locate sign units and accessories where indicated, or directed by Resident Engineer using mounting methods of the type described and in compliance with the manufacturer’s instructions.

1. Comply with the ADA Accessibility Guidelines and ICC A117.1.

B. Install signs level, plumb, and at the height indicated, with sign surfaces free from distortion or other defects in appearance.

C. Signs shall be detailed to make all edges less vulnerable to prying or removal.

D. All plaque signs shall be flush mounted, leaving no space behind sign, and installed using tamper-proof fasteners.

3.02 CLEANING, PROTECTION, AND REPAIR

A. Repair scratches and other damage which might have occurred during installation. Replace components where repairs were made but are still visible to the unaided eye from a distance of 5 feet.

B. Remove temporary coverings and protection to adjacent work areas. Clean installed products in accordance with manufacturer’s instructions prior to Acceptance. Remove construction debris from project.

3.03 SIGNAGE SIGN TYPES

A. Schedule: Refer to Signage Schedule in the Drawings for sizes, locations, and layout of signage types, sign text copy, and graphics.
Sign Types

J1.0

N5-5M21
SWITCHGEAR
TPSS

Code Room ID (8x10)
3/4" + 5/8" + Braille
White copy on Black

RW suffix:
White copy on Red

J1.1

N5-5M21
SWITCHGEAR
TPSS
ACCESS TO
MECHANICAL
ELECTRICAL

Code Room ID (8x10 and as required)
3/4" + 5/8" + Braille
White copy on Black

RW suffix:
White copy on Red

J2.0

AUTHORIZED
ACCESS ONLY

Warning (8x10)
1" Copy + Braille
Red copy on yellow

J2.1

AUTHORIZED
ACCESS ONLY
FALL
RESTRAINT
REQUIRED

(See J2.0)

J2.2

AUTHORIZED
ACCESS ONLY
DANGER
HIGH VOLTAGE

(see J2.0)

J2.3

ALARM WILL
SOUND

Alarm (8x5)
+ Braille

J2.4

SHAFTWAY

Code Warning Shaftway Sign
(8 x as required) 6" copy
White copy on red
J2.5 Traction Power Emergency Trip Station (ETS)

ETS ID
(10 x as required)
1" + 5/8" Copy
White copy on red

Caution:
Switch de-energizes both NB and SB Tracks
Contact Link Control via ETEL prior to de-energizing

J2.6 Traction Power Emergency Trip Station (ETS)

ETS ID
(10 x as required)
1" + 5/8" Copy
White copy on red

Caution:
Switches de-energize either NB or SB Tracks
Contact Link Control via ETEL prior to de-energizing

J2.7 Door to Remain Closed at All Times

Door Closed (8x6)
3/4" Copy

J3.0 Code Room ID (8x10)
3/4" + 5/8" + Braille
M+F Symbol
White copy on Black

J4.0 Stair ID (8x10)
3/4" + 1" Copy + Braille
White copy on Black
J10.0

**STAIR 2**

B2

Stairway ID (18X12)
1-1/2" + 5" copy + Braille

J10.1

**STAIR 2**

B2

Continued up to exit
Access to S, M, B1, B2, B3, B4, P

Stair Level Sign ID (12X18)
1" + 5" copy + Braille
J11.0
NO STORAGE
NO COMBUSTIBLE MATERIALS PERMITTED
NON-STORAGE/NON-COMBUSTIBLE MATERIALS ID (8" X AS REQUIRED)
1" COPY
RED COPY ON YELLOW

J12.0
DE-ENERGIZING INFORMATION
DE-ENERGIZING SIGN (8" X AS REQUIRED)
1" COPY
RED COPY ON YELLOW
CONTAINS INSTRUCTIONS TO DE-ENERGIZE HIGH-VOLTAGE ROOMS, LOCATION OF DISCONNECTING SWITCHES, PHONE NUMBERS OF KC METRO, LINK CONTROL, AND SCL PERSONNEL WHO DISCONNECT THE POWER (CONTRACTOR TO COORDINATE WITH SOUND TRANSIT), SEE SIGNAGE SCHEDULE FOR ADDITIONAL INFORMATION

J13.0
CAUTION
ROOM PROTECTED BY CLEAN AGENT
IN CASE OF FIRE KEEP DOOR CLOSED
CLEAN AGENT ID (8" X AS REQUIRED)
1" COPY
BLACK COPY ON YELLOW
SEE SPECIFICATION SECTION 21 22 00 FOR ADDITIONAL REQUIREMENTS

J14.0
KEEP CLEAR
KEEP CLEAR SIGN (8" X AS REQUIRED)
1" COPY
RED COPY ON YELLOW
J15.0

BUILDING INFORMATION SIGN (8” X AS REQUIRED)
1” COPY
RED COPY ON WHITE

J16.0

ELEVATOR CONTROL ROOM SIGN (8” X AS REQUIRED)
1” COPY
RED COPY ON YELLOW

J16.1

MACHINE ROOM INSIDE
NO STORAGE PERMITTED

FIRE ALARM SIGN (DIMENSION AS REQUIRED)
2” COPY
WHITE COPY ON RED

END OF SECTION
SECTION 10 81 13
BIRD CONTROL DEVICES

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes:
   1. Bird deterrent systems to deter birds from landing and nesting.
      a. Roof and canopy edges, structural surfaces, lights and openings to cavities and unoccupied spaces susceptible to birds landing and nesting.
      b. Elevated guideway surfaces at the column head / girder connections, joints with elastomeric bearings, and drain holes or other openings into the guideway.
   2. System types include:
      a. BCD-1: Post and wire.
      b. BCD-2: Bird spike system
      c. BCD-3: Netting.
   3. Audible bird deterrent system for use during construction.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society for Prevention of Cruelty to Animals (ASPCA)
      a. ASPCA HANDBOOK

1.03 SUBMITTALS
A. Manufacturer's descriptive product data.
B. Shop Drawings:
   1. Indicate typical layout in plan and elevation including dimensions and anchoring provisions, type design and spacing for each substrate and condition for track. Show position of track to building edge conditions for viewing angle.
   2. Submit detail drawings of special accessory components not included in manufacturer’s product data.
   3. Provide drawing showing temporary location and orientation of all audible bird deterrent components.
   4. Wiring diagrams and temporary power requirements.
C. Verification Samples:
1. Post and wire system:
   a. Wire support posts for approval.
   b. Control wire, 6 inches long each.

2. Bird Spike System
   a. 6-inch long spike strip for approvals

3. Bird net:
   a. 12-inch square section of netting.
   b. Typical cable and connector.

D. Manufacturer's Installation Instructions: Indicate preparation and installation instructions.

E. Transmit: Manufacturer's Certificate: Certify that products meet or exceed specified requirements.

F. Transmit: Qualification statements for installing mechanics.

1.04 QUALITY ASSURANCE

A. Manufacturer qualifications: Company specializing in manufacturing the products specified in this Section with minimum 3 years documented experience.

B. Installer Qualifications: Company completely familiar with installation of products similar to those required for this Contract.

C. Mock-Up
   1. Install one pin-and-wire assembly representative of each design required on Contract.
   2. Where one design may be used for different penetrating items or in different wall constructions, install one assembly for each different combination.
   3. If accepted, mock-up may remain as part of the Work. Remove and replace mock-ups that are not accepted.

1.05 DELIVERY, STORAGE AND HANDLING

A. Store and handle materials to avoid damage to products and injury to Installers.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. BCD-1: Post and Wire System
A. BCD-2: Bird Spikes
1. Acceptable manufacturers and products:
   c. Bird Busters Co.; Product: Stainless Steel Spikes; www.birdbusters.com

B. BCD-3: Bird Net
1. Bird Barrier America, Inc.: Stealth Net

2.02 POST AND WIRE SYSTEM COMPONENTS
A. Stainless steel posts with flat base minimum 4 inches by 4 inches for adhesive attachment of system to roof membrane substrate.
B. Nylon-coated stainless steel wire.
C. Stainless steel tension springs.
D. Finish: Natural stainless steel finish.

2.03 BIRD SPIKES
A. Materials:
   1. Spikes: stainless steel
   2. Width of coverage: As required.
   3. Number of spikes: Minimum 40 spikes per linear foot.
   4. Height of spikes: 4-3/4-inches
   5. Base Strip: Flexible. Base can bend up to 360°
   6. Length: 2 ft. sections
B. Finish: Natural stainless steel finish

2.04 BIRD NET COMPONENTS
A. Polyethylene twine and steel installation hardware.

2.05 CONSTRUCTION PERIOD AUDIBLE SYSTEM MANUFACTURERS AND COMPONENTS
3. Sound unit and speaker(s) for one acre coverage.
PART 3 - EXECUTION

3.01 EXAMINATION
A. Verify that installation surfaces are ready to receive architectural bird control. Do not proceed until unsatisfactory conditions have been corrected.

3.02 INSTALLATION
A. Install architectural bird control in accordance with manufacturer's printed instructions.
B. Recorded bird sounds used in audible control devices should be programmed by installer to control birds typically found in the Puget Sound Region.
C. Post and Wire System
   1. Attach bird wire posts to metal roof surfaces or to roof membrane with adhesive product approved by roofing manufacturer.
   2. Install bird wire posts at spacing specified in manufacturer's installation instructions, for uniform appearance and without end-to-end gaps.
   3. Install wire and tension springs as specified in manufacturer's installation instructions.
D. Stainless Steel Spikes
   1. Attach base with spikes to surfaces with adhesive product approved by roofing manufacturer.
   2. Follow the contours and angles closely; cut or break away to fit properly.
   3. Space materials in accordance with manufacturer's recommendations.
E. Bird Net
   1. Install perimeter cable system to structure with attachments provided for substrate material.
   2. Attach netting to cable system tightly with provided rings.
F. Decommissioning/removal of temporary audible bird deterrent equipment
G. Inspect finished installations and make adjustments as necessary.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following fall protection systems:

1. Lifeline fall-arresting cable systems; including the designing, furnishing, and installing of complete systems, as defined by OSHA; for safe maintenance and access at locations as indicated on Drawings and/or provided by design-build supplier.

2. Ladder tie offs for accessing entrance canopies, intermediate landings and other roof areas where access is needed for maintenance and permanent means of roof access cannot be provided.

3. Concrete wall and framed wall with steel back up and floor mounted tie offs.

4. Horizontal fall protection rail system for use at canopies, including attachment carriage, attachment plates, joints, corners, system stops, rail, carriage stops and specialty components for exposed and concealed conditions as required.

5. Tie off system mounted within circulation tube enclosures (Escalators).

1.02 REFERENCES

This Section incorporates by reference the latest revisions of the following documents.

A. American Institute of Steel Construction (AISC):

1. AISC S342L, with Supplement No.1 "Load and Resistance Factor Design Specification for Structural Steel Buildings".

B. American Welding Society (AWS):

1. AWS D1.1 Structural Welding Code - Steel.

2. AWS A2.4 Standard Symbols for Welding, Brazing, Nondestructive Examination

C. American National Standards Institute (ANSI):


2. ANSI Z 359.1 American National Standard Safety Requirements for Personal Fall Arrest Systems and Components


1. ASTM A123 - Standard Specification for Zinc Coating (Hot-Dip Galvanizing) of Iron and Steel Products
2. ASTM A276/A276M - Standard Specification for Stainless Steel Bars and Shapes
3. ASTM A666 - Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
5. ASTM D1056 - Standard Specification for Flexible Cellular Materials—Sponge or Expanded Rubber
6. ASTM D2000 - Standard Classification System for Rubber Products in Automotive Applications

E. Occupational Safety and Health Administration (OSHA):
1. OSHA 1926.502 Fall Prevention Systems and Criteria and Practices

1.03 SUBMITTALS

A. Detailed shop drawings showing fabrication for the complete lifeline systems as well as the safety tieback and suspension anchors.
   1. Include layout drawings of each system and anchor in relation to the supporting structure indicating the locations of all components in the system properly labeled for identification.
   2. Installation and rigging instructions and all necessary Restrictive and Non-Restrictive Working Usage Notes and General Safety Notes.
   3. Indicate welds, both shop and field, using standard welding symbols of AWS A2.4. Show the size, length, and type of each weld on drawings.
   4. Indicate individual welders' identification on Contract record drawing

B. Submit analysis data and calculations signed and sealed by the qualified structural engineer responsible for their preparation licensed to practice in the State of Washington for review by structural engineer.

C. In addition to the requirements stated elsewhere in the Contract Documents, the Operation and Maintenance Manual shall include the following:
   1. Maintenance Procedures: Including maintenance requirements for all equipment.
   3. Parts List: Include all components, listed by system. Include respective serial numbers for each component. If systems are provided at multiple locations or facilities, identify the location where individual components are located.
   4. Test Certificate: Indicating completion of proof load testing on installed systems. Include copies of approved system calculations.
   5. Product certificate: containing the manufacturer’s serial number, name and part number of each individual component used in the system; manufacturer’s catalog data indicating the sizes, descriptions, capacities, test certifications, and other
descriptive data showing sufficient detail that the product complies with the contract requirements.


7. As-Built Drawings: A copy of as-built drawings shall be included in the Operation and Maintenance Manual. As-built drawings shall include layout drawings of each system and anchor in relation to the supporting structure indicating the locations of all components in the system properly labeled for identification. In addition, mount a plastic laminated copy of the as-built shop drawing showing equipment locations and details near each exit onto the roof.

D. Transmit: Manufacturer’s Instructions: Manufacturer’s instructions indicating the manufacturer’s recommended method and sequence of installation for the following: lifeline anchors, safety tieback anchors, energy-absorbing devices, body harnesses, and lifeline cable.

E. Product Data: Material, equipment, and fixture lists. Manufacturer’s catalog data indicating the sizes, descriptions, capacities, test certifications, and other descriptive data showing in sufficient detail that the product complies with the contract requirements. Equipment and performance data including but not limited to: lifeline anchors, safety tieback anchors, energy-absorbing devices, body harnesses, lifeline cable.


1.04 QUALITY ASSURANCE

A. Manufacturer: specializing in the design, fabrication and installation of fall-arresting lifeline and safety tieback anchor systems having a minimum of 5 years documented experience.

B. Loading and safety assurance: meet the requirements of governing codes and jurisdiction and comply with properly engineered loading and safety criteria for the intended use.

C. Insurance: Manufacturer shall carry specific liability insurance (products and completed operations) in the amount of $2,000,000.00 to protect against product/system failure.

D. Welding: executed by certified welders in accordance with AWS requirements.

E. Engineering Responsibility: Preparation of Shop Drawings, design calculations, and other structural data by a qualified professional engineer registered to practice in the State of Washington.

1. Fall-Arresting System Pre-Approval: Obtain approval of Authority Having Jurisdiction before proceeding.

2. Mock-Up Requirement:
   a. Provide mock-up of each type of anchor, tie-back, safety anchor or suspension system to the Resident Engineer for approval.
   b. If accepted, mock-up shall represent minimum standard for the Work of this Section.
   c. If accepted, mock-up may remain as part of the Work. Remove and replace mock-ups that are not accepted.
1.05 REGULATORY REQUIREMENTS
   A. Comply with the following OSHA regulations:
      1. 1910, Subpart D (Walking and Working Surfaces).
      2. Appendix C to 1910 Subpart F (Personal Fall Arrest Systems).
      3. "OSHA Ruling on Window Cleaning by Bosun's Chair" Memorandum to Regional Administrators from P. K. Clark, Director, Directorate of Compliance Programs.
      4. OSHA 1926.502 Fall Prevention Systems and Criteria and Practices.

1.06 DELIVERY, STORAGE, AND HANDLING
   A. Deliver materials in manufacturer’s original unopened packaging. Store materials in original protective packaging inside a well-ventilated area protected from weather, moisture, soiling, abrasion, extreme temperatures, and humidity.

1.07 PROJECT CONDITIONS
   A. Field Measurements: Verify actual locations of structural framing and other construction contiguous with lifeline and safety tieback anchor system and window-washing suspension anchor system equipment by field measurements before fabrication and indicate measurements on Shop Drawings.

1.08 COORDINATION
   A. Coordinate installation of anchorages for anchor system equipment items and accessories with structural steel fabricator, roofing installer, and other trades that may be affected by the work.

PART 2 - PRODUCTS

2.01 MANUFACTURERS
   A. Accepted Fall-Arresting System Suppliers and Installers:
      4. DBI-SALA, www.dbifallprotection.com

2.02 PERFORMANCE REQUIREMENTS
   A. Design fall-arresting lifeline and safety tieback anchor system that will allow the user to walk uninterrupted the entire length of the system and provide secure anchorage to arrest a fall by the users in accordance with Contract Documents, standards, and regulations/codes. Design system to fully protect the user at all times while in the area of potential fall hazard. Design lifeline system for two simultaneous users. Use safety tieback and suspension anchors that are rated for attachment of a single user. Include all components required to provide a complete and fully operational system.
   B. Structural Performance: Provide fall-arresting lifeline and safety tieback anchor system capable of withstanding design loads as required by governing regulations and codes. Where component design loads are specified herein, they represent design minimum
requirements. Design the fall arresting lifeline and safety tieback anchor system and window-washing suspension anchor system as specified herein, and all associated connections to conform to the conditions shown on the Contract Drawings. Ensure that all anchor components conform to proper engineering principles and have been designed by a professional engineer who is legally qualified and registered to practice in the State of Washington where Contract is located and who is experienced in the design of fall arresting and anchoring systems, its application and safety requirements. Sound Transit takes no responsibility for product design, manufacture, delivery and handling, or connection to basic structure. Furnish and install all necessary bracing, ties, anchorage, distribution members, and similar elements in conformance with submitted drawings and calculations.

C. The Engineer retained by the Contractor shall be responsible for verifying that system components are attached in such a manner that their forces cause no distress to the basic structure. Where necessary, provide additional structural elements to safely distribute forces.

1. Provide submittal to Structural Engineer of record retained by the Contractor for review during submittal process and prior to installation.

D. Locate anchorages to suit suspension equipment used on the building with respect to items such as reach, rigging, spacing, roof edge condition, and similar items.

E. Design all anchor components to provide adequate attachment to the building and suited to current suspended maintenance practices. Ensure compatibility with industry standard equipment. Attachment of anchor post to be mechanically fastened and not welded to building structure.

F. Design system fall-arresting lifeline and safety tieback anchor system and window-washing suspension anchor system to comply with the following structural requirements

1. Safety Tieback Anchors: designed to allow the user to connect personnel fall arrest equipment and designed with a minimum 2:1 factor of safety and withstand a force of 5000 lbs.

2. Horizontal fall protection rail system designed to allow the user to connect personnel fall arrest equipment and designed with a minimum 2:1 factor of safety and to withstand a force of 5000 lbs.

2.03 PRODUCTS

A. Horizontal Life Line Fall Restraint System:

1. Intermediate cable attachment bracket.

2. Marine grade, 8mm stainless steel cable.


2.04 HORIZONTAL LIFE-LINE COMPONENTS

A. Tension Indicators and Turn-Buckles:

1. Include pretension indicator to verify and adjust correct tension of the lifeline cable.

2. Calculate cable tensions with minimum breaking strength exceeding 8,000 pounds and in conformance to manufacturer's instructions.
B. D-Rings:
1. Exceed minimum breaking strength of 10,000 pounds.
2. Fasten to supporting structure in accordance with the drawing requirements.
3. Include a lock washer under turned elements.

C. In-Line Shock Absorbers:
1. Utilize to dissipate energy generated in a fall and to reduce the end anchorage forces.
2. Exceed minimum breaking strength of 8,000 pounds.
3. Exceed 180 pound allowable normal preset tension.
4. Do not exceed activation threshold of 440 pounds.
5. Shock absorbers shall visually display deployment in the event a load such as a fall has occurred on the system.

D. Cable:
1. 7 X 7 wire rope construction.
2. 5/16 inch (8mm) diameter
3. Minimum breaking strength of 8,000 lbs.
4. Do not exceed weight of 0.18 pounds/foot
5. Terminate cable ends with swaged fittings.

E. Intermediate Supports: Design to ensure passage of the pass-through trolley over intermediate anchorage points/posts without being released from the system lifeline. D-ring Storage Cabinet:
1. Wall hanging stainless steel box painted
   a. Exterior of cabinet door: provide signage identifying contents.
   b. Interior face of cabinet door: attach instruction for the use of D-rings.
2. Capacity: Provide for each removable D-ring anchor and each removable lifting ring at each location
   a. Include removable flush plug device for each removable anchor, plus 10% spares.
3. Finish: As selected by Resident Engineer
4. Location: As noted on Drawings

F. Attachment Transfastener/Trolley: Manufacturer’s standard stainless steel attachment trolley. Trolley shall allow for easy pass-through of support points without disconnecting from the system.
1. Minimum tensile strength 3600 lbs.
2. Provide 4 carriages per system type at each facility
2.05 HORIZONTAL FALL PROTECTION RAIL SYSTEM AT EXTERIOR CANOPIES

A. Basis of design: 3M Fall Protection; DBI-SALA® Roofsafe™ Rail System

B. Components:

1. Rail: Low profile 1-1/4 -inches by 1-1/4-inches aluminum extrusions
2. Rail Joint: Low profile, aluminum extrusion to connect to rail sections
3. Corners: Additional bends and forms available to a radius of 7-7/8- inches.
4. System Stops: Manufacturer's standard stops which prevent rails from coming out of end anchorage bracket.
5. Molded Ends: Manufacturer's standard molded ends which protect exposed edge of end rails.
6. Tamper-Proof Carriage Stops: Manufacturer's standard tamper-proof, carriage stops which prevent carriages from coming off the end of the system.
7. Removable Carriage Stops: Manufacturer's standard tamper-proof, carriage stops which prevent carriages from coming off the end of the system but can be removed to allow the carriages to be taken off.
8. Attachment Carriages: Manufacturer’s standard aluminum attachment carriage with aluminum, nylon coated wheels. A stainless steel shackle with carabiner hook which pivots for any angle connection.
    a. Minimum tensile strength 3370 lbs.
    b. Provide 4 carriages per rail length

2.06 PERMANENT MOUNTED D-RING BOLT ANCHOR

A. Manufacturers

1. Basis of design: Protecta AN111A
2. 3M Fall Protection
3. Miller Fall Protection

B. Component:

1. Stainless steel D-bolt anchor up to 4-inches working thickness, with 5/8-inch diameter bolt with lock washer and nut.
2. Capacity: Each anchorage connector to support 5,000 pounds per worker.

2.07 REMOVABLE CONCETE DETENT ANCHOR

A. Basis of design:

1. DBI-Sala Concrete Detent Anchor with removable D-ring
2. Guardian Fall Protection

B. Component:
1. Concrete detent anchor for hole with reusable detent pin D-ring assembly, socket and cap.

2. Capacity: Each anchorage connector to support a load of 5,000 lbs.

2.08 FASTENERS
A. Bolts, Nuts, and Washers: Type 304 or 316, stainless steel.
B. Exposed Fasteners: As designed by manufacturer to accommodate deck type, structural framing, and design loads.

2.09 FLASHING AND SEALING MATERIALS
A. Non-Expanding Sealing Gaskets: Pre-cut and predrilled, 40 durometer, 1/8 inch, solid neoprene rubber meeting or exceeding ASTM D2000. For sealing under anchor bases.
B. Expanding Compression Gaskets: EPDM or Neoprene rubber meeting or exceeding ASTM D1056 Type I (Closed Cell), Class B or C (Petroleum Resistant).
C. Joint Sealants: Non-skinning butyl sealant or neutral curing silicone sealant as specified Section 07 92 00. Polyurethane sealant not accepted.

2.10 FABRICATION
A. Fabricate work true to dimension, square, plumb, level and free from distortion or defects detrimental to appearance and performance.
B. Grind off surplus welding material and ensure exposed internal corners have smooth lines.
C. Fabricate system components of the same material unless otherwise indicated.
D. Fabricate anchoring devices as recommended by the manufacturer to provide adequate support for intended use.
E. Fabricate joints in a manner to discourage water accumulation. Provide weep holes to drain all water that could accumulate in the exposed joints.

PART 3 - EXECUTION

3.01 EXAMINATION
A. Examine substrates and conditions for compliance with requirements for installation tolerances and other conditions upon which the work of this Section depends. Report to the Contractor in writing defects in work prepared by other trades and other unsatisfactory site conditions that would cause defective installation of products or cause latent defects in workmanship and function.
   1. Proceed with installation only after unsatisfactory conditions have been corrected.
   2. Commencement of work shall imply acceptance of prepared work.
3.02 INSTALLATION, GENERAL
   A. Install equipment in accordance with approved shop drawings and manufacturer's instructions.
   B. Coordinate installation with work of related trades.
   C. Install all work true, level, tightly fitted, and flush with adjacent surfaces as required.
   D. Deform threads of tail end of anchor studs after nuts have been tightened to prevent accidental removal or vandalism.
   E. Lifeline systems and anchors: installed by manufacturer’s authorized, trained, and certified personnel.
   F. For requirements for anchors in concrete refer to anchorage to concrete as stated elsewhere in the Contract documents. For other building attachment locations install with mechanical fasteners only.
   G. Install anchorage and fasteners in accordance with manufacturer’s recommendations to obtain the allowable working loads published in the product literature and in accordance with these Contract Specifications.
   H. Do not load or stress lifeline systems or anchors until all materials and fasteners are properly installed and ready for service.
   I. Install all lifeline systems and anchors a minimum of 6 feet from the roof edge.

3.03 FINAL ADJUSTING AND INSPECTION
   A. Adjust and leave equipment in proper working order.

3.04 TESTING
   A. Test using load cell test apparatus in accordance with manufacturer’s recommendations.

3.05 CLEANING
   A. Unless otherwise indicated, clean metals by washing thoroughly with clean water and soap, rinsing with clean water, and drying with soft cloths.

3.06 TRAINING
   A. Provide a minimum of 4 hours of operator training after system has been installed and proof tested. Provide hands-on training for the users of the system and conduct at the installation site.

3.07 PROTECTION
   A. Protect roof mounted horizontal maintenance equipment and accessories from damage during construction period with temporary protective coverings approved by manufacturer. Remove protective covering at time of Substantial Completion.
   B. Restore finishes damaged during installation and construction period so no evidence remains of damaged work. Return items that cannot be refinished in the field to the shop; make required alterations and refinish entire unit, or provide new units.
3.08 COMMISSIONING

A. Certification of fall protection system: Provide and maintain certification for the duration of construction once system is installed and at project closeout.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing and providing Maintenance for Gearless Passenger traction elevators as specified and detailed on the Contract Drawings.

B. Related Work Provided Under Other Sections

1. Hoistway and Pit:
   a. Clear, plumb, substantially flush hoistway with variations not to exceed 1 inch at any point.
   b. Bevel cants not less than 75 degrees from the horizontal on any rear or sidewall ledges and beams that project or recess 2 inches or more into the hoistway. Not required on hoistway divider beams.
   c. Supports at each floor for car and counterweight guide rail fastening. Intermediate car and counterweight guide rail support when floor heights exceed 14 feet 0 inch. Building supports not to deflect more than 1/8 inch under normal conditions, 1/4 inch under seismic conditions.
   d. Installation of guide rail bracket supports in concrete. Inserts or embeds, if used, will be furnished under this Section.
   e. Wall blockouts and fire rated closure for control and signal fixture boxes that penetrate walls.
   f. Cutting and patching walls and floors. Finished floors slope away from elevator doors.
   g. Wall pockets and/or structural beams for support of machine, sheave, and dead-end hitch beams. Do not exceed support deflection of 1/166 of span under static load. Erect from elevator hoistway wall after elevator entrances.
   h. Grout around hoistway entrances and sills.
   i. Pit access ladder for each elevator.
   j. Structural support for car and counterweight buffer impact loads, guide rail loads, and compensation sheave tie-down upthrust.
   k. Waterproof pit. Dry sump with flush grate or indirect drain.
   l. Protect open hoistways and entrances during construction in accordance with OSHA Regulations 29 CFR Part 1926.
   m. Protect car enclosure, hoistway entrance assemblies, and special metal finishes from damage after installation.
n. Hoistway venting or pressurization to prevent accumulation of smoke and gas as required by Local Building Code.

o. Seal fireproofing to prevent flaking.

2. Machine Room, Control Room and Machinery Spaces:
   a. Self-closing and locking access door.
   b. Ventilation and heating.
      1) Minimum temperature: Maintain minimum temperature of 55 degrees F.
      2) Maximum temperature: Maintain maximum temperature of 90 degrees F.
      3) Maintain maximum 80 percent relative humidity, non-condensing
   c. Paint walls, ceiling, and floor.
   d. Class ABC fire extinguisher.
   e. Seal fireproofing to prevent flaking.
   f. Fire sprinklers as required by code.

3. Electrical Service, Conductors, and Devices:
   a. Lighting and Ground Fault Circuit Interrupter (GFCI) convenience outlets in pit, machine room, and overhead machinery space.
   b. Conduit from the hoistway of each elevator to the firefighter’s control room and communications distribution cabinet. Coordinate size, number, and location of conduits.
   c. Three-phase mainline copper power feeder to terminals of each elevator controller in the machine room with protected, lockable OPEN, disconnect switch.
   d. Single-phase copper power feeder to each elevator controller for car lighting and exhaust blower with individual protected, lockable OFF, disconnect switch.
   e. Products-of-combustion sensor (NFPA No. 72, Chapter 5-3) in each elevator lobby, for each group of elevators or single elevator and each machine room to initiate firefighters’ return feature. Locate device at top of hoistway if sprinklered. Provide means for service access from outside the hoistway. Provide sensor signal wiring from hoistway or machine room connection point to elevator controller terminals.
   f. Temporary power and illumination to install, test, and adjust elevator equipment.
   g. Means to manually and automatically disconnect power to affected elevator drive unit and controller prior to activation of machine room overhead fire sprinkler system, and/or hoistway overhead fire sprinkler system. Locate manual shut-off means outside bounds of machine room.
h. When sprinklers are provided in the hoistway, identify all electrical equipment, except seismic protective devices, located less than 4 feet 0 inch above the pit floor for use in wet locations. (ANSI/NFPA 70).

i. Power feeders to main control console and firefighters’ control panel.

j. Power feeder to elevator Public Address (PA) amplifier in the elevator machine room.

k. Single-phase power feeders to machine room elevator group control monitor with single-phase, protected, lockable OFF, disconnect switch.

4. Standby Power Provision:

a. Standby power of the same voltage characteristics via normal electrical feeder to run all elevators at full-rated car speed and capacity.

b. Conductor from auxiliary form “C” dry contacts, located in the standby power transfer switch to a designated elevator control panel in each elevator group and/or single elevator unit. Provide time delay of 30-45 seconds for pre-transfer signal in both directions.

c. Standby single-phase power to group controller, and each elevator controller for lighting, exhaust blower, emergency call bell, intercom amplifier, and hoist machine cooling fan.

d. Means for absorbing regenerated power during an overhauling load condition, in accordance with NEC 650-101. Elevator shall employ SCR IBGT drive, presenting a non-linear active load.

e. IBC Rule 3005.1 requires elevator machine room ventilation or air conditioning to function under a standby power condition.

C. Equipment furnished by Sound Transit, installed under this Section:

1. Network Switch

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Society of Mechanical Engineers (ASME)

   a. ASME A17.1 National Safety Code for Elevators and Escalators

   b. ASME A17.2.1 Inspector’s Manual for Electric Elevators

   c. ASME A17.5 Elevator and Escalator Electrical Equipment


   a. ASTM A36 Standard Specification for Carbon Structural Steel


   c. ASTM A568 Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements
d. ASTM A1008 Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability

e. ASTM A1011 Standard Specifications for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy with Improved Formability

f. ASTM B209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

g. ASTM B221 Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles and Tubes

3. National Fire Protection Association (NFPA)
   a. NFPA No. 70 National Electrical Code
   b. NFPA No. 72 National Fire Alarm Code
   d. NFPA No. 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

4. Federal Standard and NAAMM nomenclature

5. American National Standards Institute (ANSI)
   a. ANSI Z97.1 Safety and Glazing Materials used in Building Safety

6. Telecommunications Industry Association (TIA)
   a. TIA-568-C.0 Generic Telecommunications Cabling for Customer Premises

   a. CPSC 16 CRF Part 1201 Safety Standard for Architectural Glazing Materials

8. Washington Administrative Code (WAC)

9. Occupational Safety & Health Administration (OSHA)
   a. 29 CFR Part 1926, Safety and Health Regulations for Construction

10. Americans with Disabilities Act of 1990 (ADA)

11. Seattle Building Code (SBC)

12. American National Standards Institute (ANSI)

13. Federal Communications Commission (FCC)
   a. EMI Shielding Guidelines
1.03 DEFINITIONS

A. Terms used are defined in the latest edition of the Safety Code for Elevators and Escalators, ASME A17.1.

B. Reference to a device or a part of the equipment applies to the number of devices or parts required to complete the installation.

1.04 SUBMITTALS

A. Pre-revenue Warranty Maintenance Plan
   1. Submit a detailed Pre-revenue Warranty Maintenance Plan.

B. Shop Drawings: Scaled and Fully Dimensioned Layout that includes plans of pit, hoistway, and machine room indicating equipment arrangement, elevation section of hoistway, details of car enclosures, hoistway entrances, and car/hall signal fixtures.
   1. Indicate equipment lists, reactions, and design information on layouts.
   3. Complete control and schematic wiring diagram of the elevator system and subsystems.
   4. Elevator controller, including manufacturer's technical data and product data, and interface hardware and software requirements.
   5. Within 60 days after Notice to Proceed and before beginning equipment fabrication, submit shop drawings and required material for review.

C. Testing Submittals
   1. Submit fiber optic performance test procedure and results.

D. Product data for Special Elevator Equipment: Submit product catalogs for speakers, cameras, intercom/emergency telephone, Ethernet switch, traveling cable data cables, card reader and door controllers.

E. The Contractor shall submit material safety data and product data sheets for all products used by the Contractor at the site or which may need to be replaced or added to by the maintenance personnel. Such products include but are not limited to greases, oils and paint. The sheets shall have an index listing each product along with application method, approximate quantity required of the product and the component the product is associated with.

F. Finish Material: Submit 3-inch by 12-inch samples of actual finished material for review of color, pattern, and texture of exposed finishes. Compliance with other requirements is the exclusive responsibility of the Contractor.

G. Operation and Maintenance Manuals
   1. In addition to the requirements stated elsewhere in the Contract Documents, include the following as minimums:
      a. Printed Instructions explaining all operating features.
      b. Complete installation, maintenance, adjustment, removal, and testing instructions and procedures for all elevator equipment and components.
All instructions shall be at the adjuster’s level and specific to the equipment installed.

1) Include inspection and maintenance standards including wear limits, settings and tolerances.

c. Wiring Diagrams: Include a complete set within each Operation and Maintenance Manual, as well as three individually printed and bound complete sets, of as-installed straight-line wiring diagrams showing the electrical connections of all equipment and all modifications to control circuits, including wiring of safety devices. Furnish a legend sheet with each set of drawings to provide the following information:

1) Name and symbol of each relay, switch, or other apparatus.
2) Location on drawings, drawing sheet number and area, and location of all contacts.
3) Location of apparatus, whether on controller or on car.
4) Sequence of operation of apparatus connected with each elevator.

d. Complete software documentation for all installed equipment, including software updates and or revisions during the progress of the work.

e. Lubricating instructions and schedule, including recommended grade of lubricants.

f. Hoistway cleaning procedures required to meet sign off requirements of L&I.

g. List of Special Tools required for inspection, adjustment, maintenance, repair and testing.

h. List of recommended spare parts and stock quantities for routine maintenance of the equipment. Include a list of spare parts considered critical and for which long lead time frames for acquisition would result in extended equipment down-time.

i. Parts Catalog: Complete parts catalogs listing all replaceable parts including Manufacturer’s identifying numbers, current unit price and ordering instructions. Include the complete parts catalog in each Operation and Maintenance Manual, as well as three separate complete printed sets.

j. The Operation and Maintenance Manual shall contain only information related to the equipment installed. Generic information not relevant to the installed equipment shall not be included.

H. Special Tools

1. Provide a complete set of special tools and instruments necessary for troubleshooting and making all adjustments on every part of the elevator installation. Any tools that are designed specifically for tasks associated with elevator inspection, maintenance and repair or that are required for these tasks, are special tools.

2. Diagnostic equipment: Provide all diagnostic test devices complete with instructions, access codes, adjusters’ manuals and set-up manuals for
adjustment, diagnosis and troubleshooting of elevator system, and performance of routine safety tests.

3. Storage cabinet: Provide and install a lockable metal cabinet in each elevator machine room of suitable size for the storage of special tools and necessary spare parts. Cabinet shall be mounted on legs or a pedestal a minimum of 4 inches off the floor. Cabinet to be keyed to Sound Transit standard keying system.

I. Four sets of neatly tagged keys for all switches and control features properly tagged and marked.

1.05 QUALITY ASSURANCE

A. Comply with most stringent applicable provisions of following Code and/or Authority, including revisions and changes in effect on date of these Specifications:

1. Safety Code for Elevators and Escalators, ASME A17.1
2. Inspectors’ Manual, ASME A17.2.1
3. Elevator and Escalator Electrical Equipment, ASME A17.5
4. National Electrical Code, NFPA 70
5. Americans with Disabilities Act (ADA)
6. Local fire jurisdiction
7. Requirements of SBC with local municipality amendments and all other Codes, Ordinances and Laws within the governing jurisdiction
9. Washington Administrative Code (WAC)

1.06 DELIVERY, STORAGE, AND HANDLING

A. Deliver material in Manufacturer’s original, unopened protective packaging.

B. Store material in original protective packaging. Prevent soiling, physical damage, or moisture damage.

C. Protect equipment and exposed finishes from damage and stains during transportation, erection, and construction.

1.07 MAINTENANCE

A. Pre-revenue Warranty Maintenance:

1. Provide full service Warranty Maintenance as described in this section. This period shall commence upon installation and extend to the start of Revenue Service.

   a. Full service maintenance shall include standard monthly maintenance, replacement parts, and annual testing.

2. Provide preventive maintenance, as recommended by the manufacturer and in accordance with all applicable codes, during normal working hours. Systematically examine, adjust, clean, and lubricate equipment, parts,
components, and subsystems. Repair or replace defective parts using parts produced by the manufacturer of installed equipment. Maintain elevator machine room, hoistway, and pit in clean condition.

3. Defective is defined to include, but not to be limited to; operation or control system failures, performance below required minimum, excessive wear, unusual deterioration or aging of materials or finishes, unsafe conditions, the need for excessive maintenance, abnormal noise or vibration, and similar unsatisfactory conditions.

4. Exercise each elevator during monthly maintenance visits. Exercising of equipment shall consist of continuous operation through entire run of hoistway for one hour. Exercise equipment as necessary to meet a minimum of 150 hours of run time in the first year.

5. All warranty and maintenance work shall be performed by a company that has a current code compliant Maintenance Control Program (MCP) on file with L & I. Warranty maintenance shall meet the MCP criteria as outlined in ASME A17.1 as well as all manufacturer’s recommended maintenance.

6. Equipment Manufacturer is responsible for upgrades and revisions of software and documentation of associated revision to the Operations and Maintenance Manual.

7. The Contractor shall document all maintenance and transmit maintenance records to Sound Transit.

B. Extended Warranty Maintenance:

1. Provide Extended Warranty Maintenance for a five year period commencing at the start of Revenue Service, per Appendix A “Extended Maintenance Services Scope of Work” and as generally described below.

2. Provide full service preventive maintenance as recommended by the manufacturer and in accordance with all applicable codes, and 24-hour emergency callback service. Systematically examine, adjust, clean, and lubricate equipment, parts, components, and subsystems. Repair or replace parts as necessary using parts produced by the manufacturer of installed equipment. Maintain elevator machine room, hoistway, and pit in clean condition.

3. Removal of units from beneficial usage for maintenance purposes shall be coordinated with and approved by Sound Transit, unless removal is necessitated for emergency repair or adjustment. Normal preventive maintenance service shall be performed during off-peak operating hours.

4. All units shall be available for use an average of 98.7% of property hours of operation over each three-month period during Extended Warranty Maintenance service. This includes allowance for equipment out of service time as the result of callbacks, scheduled preventive maintenance, and repairs. Contractor’s failure to meet this unit availability provision for two consecutive three-month periods for any single elevator or escalator, or group of units, shall trigger an automatic maintenance audit by Sound Transit. Contractor agrees to expeditiously take corrective action in regard to identified deficiencies. Further, Contractor acknowledges Sound Transit’s right to pass cost of said audit to Contractor.
5. All warranty and maintenance work shall be performed by a company that has a current code compliant Maintenance Control Program (MCP) on file with L & I.

6. Equipment Manufacturer is responsible for upgrades and revisions of software and documentation of associated revision to the Operations and Maintenance Manual.

1.08 PERMIT, TEST AND INSPECTION

A. Obtain and pay for permit, license, and inspection fee necessary to complete the installation. Installation will be considered complete when the governing authority of Washington State Department of Labor and Industries has issued a permanent operating permit for each elevator.

B. Perform tests required by the elevator Section of the Washington State Department of Labor and Industries. Perform tests in accordance with procedures described in ASME A17.2.1 inspector’s manual for Electric Elevators and as required by the authorities having jurisdiction in the presence of the Resident Engineer.

C. Contractor is not relieved from furnishing and installing work shown or specified which may be beyond requirements of ordinances, laws, regulations or codes.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Approved Manufacturers:

1. Installers: KONE, Schindler, ThyssenKrupp or approved equal.

2. Gearless Machines: Manufacturers standard

3. Control Manufacturers: KONE, Schindler or Thyssenkrupp standard (non-proprietary) controls, MCE, and Swift/CEC.

4. Car Enclosure: Brice-Southern, Hauenstein & Burmeister, KONE, Schindler, Thyssenkrupp, Tyler, Concept or approved equal.


2.02 MATERIALS

A. Steel:


B. Stainless Steel: Type 316 complying with ASTM A167, with standard tempers and hardness required for fabrication, strength and durability. Apply mechanical finish on fabricated work in the locations shown or specified (Federal Standard and NAAMM nomenclature) with texture and reflectivity required to match Resident Engineer’s sample. Protect with adhesive-paper covering.
1. Non-directional orbital uniform finish: 80 grit orbital sanding over standard mill plate or shape to produce a uniform non-directional satin finish with 90 percent of mill marks removed to match Resident Engineers visual sample.

C. Aluminum: Extrusions conforming to ASTM B221. Sheet and plate conforming to ASTM B209.

D. Nickel Silver: Extrusions conforming to ASTM B151/151M.

E. Paint: Clean exposed metal of oil, grease, scale, and other foreign matter and factory paint one shop coat of Manufacturer’s standard rust-resistant primer. After erection, provide one finish coat of industrial enamel paint. Galvanized metal need not be painted. See Section 09 96 00, High Performance Coatings.

F. Prime Finish: Clean all surfaces receiving a baked enamel paint finish of oil, grease, and scale. Apply one coat of rust-resistant mineral paint followed by a filler coat over uneven surfaces. Sand smooth and apply final coat of mineral paint.

G. Baked Enamel Finish: Prime finish in accordance with Article 2.02E above. Apply and bake two additional coats of enamel in the selected solid color.

H. Glass: Laminated safety glass, minimum 9/16 inch thick, conforming to ANSI Z97.1 and CPSC 16 CFR Part 1201 and Contract Specifications Section 08 80 00, Glazing, Article 2.01.

2.03 EQUIPMENT

A. Equipment shall be the same for all contracts except where specifically noted. Where variations occur, each contract shall be specified separately.

B. Elevator Features

1. Number:
   a. As specified and as detailed on the Contract Drawings

2. Capacity and Loading Classification:
   a. As specified and as detailed on the Contract Drawings

3. Speed:
   a. Rises greater than 50 feet: 350 feet per minute (fpm)
   b. Rises 50 feet or less: 200 feet per minute (fpm)

4. Roping: Manufacturer’s standard roping configuration per Contract Drawings.

5. Supervisory Control: Selective collective, microprocessor based system, non-proprietary

6. Motor Control: Variable voltage variable frequency (VVVF), microprocessor based with digital closed loop feedback and automatic stopping

7. Power Characteristics: 480 volts, 3 phase, 60 hertz

8. Stops and Openings: As detailed on the Contract Drawings.

10. Travel: As detailed on the Contract Drawings

11. Minimum Clear Inside Car:
   a. Geometry Type A: 5 feet 8 inches wide by 7 feet 10 inches deep.
   b. Geometry Type B: 7 feet 8 inches wide by 5 feet 3 inches deep.

12. Entrance Size: 4 feet 0 inches wide by 7 feet 0 inches high.

13. Entrance Type: As detailed on the Contract Drawings

14. Door Operation: High speed, heavy duty, door operator, minimum opening speed 2.5 feet per second (fps).

15. Door Protection: Infrared, full screen device, with differential timing and nudging and interrupted beam time.


18. Safety: Flexible guide clamp - Type B, car only.


23. Registration Lights: Single hall pushbutton riser at each opening. Vandal resistant car and hall pushbuttons.
   a. Hall buttons and control devices shall be NEMA 4.


25. Firefighters’ elevator control panel located in Fire Command Center and remote wiring.

26. Hall Lanterns: At all floors with volume adjustable electronic chime or tone. Sound twice for down direction. Vandal resistant
   a. Hall lanterns shall be in NEMA 4 enclosures at all locations.

27. Hoistway wiring, conduit and enclosures shall be rated for wet locations.

28. Additional Features.
   a. Roller guides
   b. Car top inspection station
   c. Guardrails at car top to meet code requirements for safety.
   d. Firefighters’ service, including alternate floor return feature
e. Standby power transfer (automatic to main floor) with manual override in fire control panel
f. Battery return device, if emergency power is provided per construction documents
g. Accessibility and emergency medical services access and signage
h. Hinged car return panels arranged for integral car operating panels
i. Hoistway access switches
j. Hoistway door unlocking device all floors with keyed escutcheon plugs
k. Independent service feature
l. Platform isolation
m. Load weighing device
n. Anti-nuisance feature
o. Firefighters’ elevator control panel located in Fire Command Center Room and remote wiring.
p. Tamper resistant fasteners for signal fixture faceplates
q. Sill support angles
r. Machine, power conversion unit, and controller sound isolation
s. Seismic devices in accordance with ASME A17.1, Section 2400
t. Pad hooks and vinyl-covered pads
u. Battery pack emergency car lighting. Provide separate constant pressure test button in car service compartment. Illuminate portion of normal car lighting
v. Signage engraving filled with black paint or approved etching process
w. Etched stainless steel support signs, interior cab only
  1) Material: Stainless steel, etched copy and icon. Attached to interior elevator walls with VHB and silicone.
  2) Thickness: 1/8 inch thick with eased edges
  3) Size: 3-inch x 1-1/4-inch
  4) Braille message: Stainless steel braille beads applied below 1/32-inch raised copy and Grade II braille.
  5) Color: Reverse etched stainless steel, negative space is painted black
x. No visible company name or logo on any equipment viewable by passengers
y. Auxiliary car operating panel for dual entry elevators.
z. Wiring diagrams, operating instructions, and parts ordering information

aa. System Diagnostic Equipment and instructions: The elevator installation shall be a design that can be maintainable by any licensed elevator maintenance company employing journeymen mechanics, without the need to purchase or lease additional diagnostic devices, special tools, or instructions from the original equipment manufacturer.

1) Provide onsite capability to diagnose faults to the level of individual circuit boards and individual discreet components for the solid state elevator controller.

2) If the equipment for fault diagnosis is not completely self-contained within the controllers but requires a separate, detachable device, that device shall be furnished to Sound Transit as part of this installation. Such device shall be in possession of and become property of Sound Transit.

   a) Installed equipment not meeting this requirement shall be removed and replaced with conforming equipment at no cost to Sound Transit.

bb. Non-proprietary control system and diagnostics provisions


dd. Firefighters' Key Box: Knox-Box Elevator Key Box 1400 Series recessed mount and recessed mounting kit, or approved equal. Color: Red. Engrave instructions for use on cover in accordance with Local Fire Authority requirements. Locate box as shown on drawings. Refer to Architectural drawings for location.

ee. Keys for elevator access and car operating panel in the machine room.

C. Car, General

1. Car Speed: Plus or minus 3 percent of Contract speed under all loading conditions.

2. Car Capacity: Safely lower, stop and hold 125 percent of rated load.

3. Car Stopping Zone: Plus or minus 1/4 inch under all loading conditions.

4. Door Opening Time:

   a. Two speed, side opening: 2.7 seconds from start of opening to fully open.

   b. Single speed center opening: 1.8 seconds from start of opening to fully open.

5. Door Closing Time:

   a. Two speed side opening: 4.5 seconds from start of closing to fully closed.
b. Single speed center opening: 2.8 seconds form start of closing to fully closed.

6. Car Ride Quality
   a. Horizontal acceleration within car during all riding and door operating conditions. Not more than 20 mg peak to peak in the 1-10 Hertz range.
   b. Acceleration and Deceleration: Smooth constant and not more than 5 feet/second/second with an initial ramp between 0.5 and 0.75 second.
   c. Sustained Jerk: Not more than 8 feet/second/second/second

7. Airborne Noise: Measured noise level of elevator equipment during operation shall not exceed 50 decibels (dBA) in elevator lobbies. Noise Level in cab shall not exceed 55 dBA for continuous noise or 60 dBA for intermittent noise.
   a. Take all dBA readings 5 feet off the floor and 1 foot or more from wall.

D. Car Equipment
1. Frame: Welded or bolted, rolled or formed steel channel construction to meet load classification requirements.
2. Safety Device: Type B, flexible guide clamp.
4. Guide Shoes: Roller type with three or more spring-dampened, sound-deadening rollers per shoe. Minimum roller diameter 6 inches.
5. Finish Floor Covering: Resin Epoxy flooring: seamless, flexible, resilient flooring system with high solids with colored rubber chips in a troweled mortar system. 1/4-inch thickness. “SofTop” Decorative Flooring by Sherwin Williams or approved equal, with “Shark-Grip” Slip Resistant additive. Color as selected by Resident Engineer from manufacturer’s standard.
6. Sills: One piece nickel silver extrusion with extruded extension between car entrance columns to face of car front return. Extruded extension to match finish of sill.
7. Toe Guard: Minimum 14-gauge stainless steel reinforced and braced to car platform, with flat black finish.
8. Doors: Provide as specified for hoistway entrance doors.
9. Finger Guard: Brush type to prevent entrapment during door opening. Provide complete with cover plate to conceal fixings and coordinate with surrounding finishes.
10. Door Hangers: Two-point hanger roller with neoprene roller surface and suspension with eccentric upthrust roller adjustment.
11. Door Track: Bar or formed, cold-drawn removable steel track with smooth roller contact surface.
12. Door Header: Construct of minimum 12-gauge steel, shape to provide stiffening flanges.
13. Door Electrical Contact: Prohibit car operation unless car door is closed within tolerance allowed by Code.

14. Door Clutch: Heavy-duty clutch, linkage arms, drive blocks, and pickup rollers or cams to provide positive, smooth, quiet door operation. Design clutch so car doors can be closed while hoistway doors remain open.

15. Restricted Opening Device: Restrict opening of car doors outside the unlocking zone.

16. Door Operator: High speed, heavy-duty master door operator capable of opening doors at no less than 2.5 fps. Accomplish reversal in no more than 2 and 1/2 inches of door movement. Open doors automatically when car arrives at a floor. Provide solid state door control with closed loop circuitry to constantly monitor and automatically adjust door operation based upon velocity, position, and motor current. Maintain consistent, quiet, and smooth door operation at all floors regardless of door weight or varying air pressure up to 0.5-inch W.C. Basis of Design: GAL MOVFR or approved equal.

17. Door Control Device:
   a. Infrared Reopening Device: Black, fully enclosed device. Full screen infrared matrix or multiple beams extending vertically along edge of each leading door panel to minimum height of 7 feet above finished floor. Device shall prevent doors from closing and reverse doors at normal opening speed if beams are obstructed while doors are closing, except during nudging operation. If device fails, provide for automatic shutdown of car at floor level with doors open.
   
   b. Nudging Operation: After beams of door control device are obstructed for a predetermined time interval (minimum 20.0 to 25.0 seconds), warning signal shall sound and doors shall attempt to close with a maximum of 2.5 foot-pounds kinetic energy. Activation of the door open button shall override the nudging operation and re-open the doors.
   
   c. Interrupted Beam Time: When beams are interrupted during initial door opening, hold door open a minimum of 3.0 seconds. When beams are interrupted after the initial 3.0-second hold open time, reduce time doors remain open to an adjustable time of approximately 1.0 to 1.5 seconds after beams are reestablished.
   
   d. Differential Door Time: Provide separately adjustable timers to vary time that doors remain open after stopping in response to calls.
      1) Car Call: Hold open time adjustable between 3.0 and 5.0 seconds.
      2) Hall Call: Hold open time adjustable between 5.0 and 8.0 seconds. Use extended hall call time when car responds to coincidental calls.

18. Car Operating Panel:
   a. One car operating panel without faceplate consisting of a stainless steel box containing the operating vandal resistant fixtures, mounted behind the car enclosure swing return panel(s).
      1) Panel shall be located as detailed in the Contract Drawings and as required by entrance type.
b. Suitably identify vandal resistant assemblies including floor buttons, alarm button, door open button, door close button, and emergency stop switch with SCS, Visionmark or Entrada Cast tactile symbols rear mounted. Provide plates in accordance with Local Accessibility Standards including Braille. Locate operating controls no higher than 48 inches above the car floor; no lower than 35 inches for stop device and alarm button.

c. Provide minimum 3/4-inch diameter raised 1/8 inch with square shoulders or flush floor pushbuttons, which illuminate to indicate call registration. Include 5/8-inch high designation of the floors served directly to the left of the pushbutton. Provide keyswitches to activate floor pushbuttons at intermediate levels. Platform and surface levels to have pushbutton only.

1) Elevator car call buttons shall indicate floor levels consistent with Sound Transit’s standard floor identification as follows:
   a) $P =$ Platform Level
   b) $M =$ Mezzanine Level (1, 2, 3, etc.)
   c) $B =$ Basement Level (1, 2, 3, etc.)
   d) $S =$ Surface Level

d. Provide alarm button at bottom of car operating panel to ring bell located on car, and sound distress signal at control panel. Illuminate button when activated.

e. Provide keyed stop switch with markings to show run and stop located in locked car service compartment.

f. Provide door open button to stop and reopen closing doors or hold doors in open position. Button operable only while car is stopped at floor regardless of special operational features, except firefighters’ service.

g. Provide door close button to activate door close cycle. Cycle shall not begin until normal door dwell time for a car call has expired except firefighters’ service.

h. Provide firefighters’ Phase II keyswitch with engraved instructions in accordance with Code requirement. Include light jewel, buzzer, and call cancel button.

i. Provide seismic indicator jewel.

j. Provide lockable service compartment with recessed flush door. Door material and finish shall match car return panel or car operating panel faceplate. Door shall contain an integral flush window for displaying the elevator-operating certificate. Inside surface of door shall accommodate mounting provisions for certificate.

1) Include the following controls in lockable service cabinet with function and operating positions identified by engraved letters painted black.
   a) Inspection switch.
   b) Light switch.
2) 2-speed exhaust blower switch.

3) Independent service switch.

4) Constant pressure test button for battery pack emergency lighting.

5) 120-volt, AC, GFCI protected electrical convenience outlet.

6) Card reader override switch.

7) Stop switch.

k. Provide black paint filled, engraved or approved etched signage with size and style approved by the Resident Engineer as follows:

1) Phase II firefighters’ operating instructions on main operating panel above corresponding keyswitch, with text in accordance with ASME A17.1 211.7(b).

2) Elevator car number over main car operating panel.

3) NO SMOKING over main car operating panel.

4) Car capacity in pounds on service compartment door.

5) Washington State Department of Labor and Industries conveyance number in ½-inch tall letters.

19. Car Top Control Station: In accordance with Code. Control station shall be provided with GFCI protected outlet and work light; include on/off switch and lamp guard. An additional GFCI receptacle shall be mounted at bottom of car. Mount to provide utilization while standing in an upright position.

E. Car Enclosure

1. Provide complete car enclosure as specified herein and detailed on the Contract Drawings. Provide the following features.


b. Canopy: Reinforced 14-gauge furniture steel with lockable, hinged emergency exit. Interior finish white reflective baked enamel.

c. Front and Rear Return Panels and Integral Entrance Columns: Reinforced 14-gauge non-directional finish stainless steel. Swing entire unit on substantial pivot points (minimum three) for service access to car operating panel(s). Locate pivot points to provide full swing of front return panel without interference with sidewall finish or handrail. Secure in closed position with concealed three-point latching. Provide service compartment with recessed flush cover and cutouts for operating switches.

d. Transom: Reinforced 14-gauge non-directional finish stainless steel full width of enclosure.

e. Car Door Panels: Minimum reinforced 16-gauge non-directional stainless steel. Same construction as hoistway door panels.
f. Base: Non-directional stainless steel with concealed ventilation cutouts. Cutouts to be protected from penetration by debris or liquids.

g. Interior Wall Finish: Non-directional finish stainless steel on aluminum honeycomb panels. As specified and as indicated. Refer to architectural drawings for details of elevator cab interiors including metal and glass panel installations.

h. Ventilation: Two-speed exhaust blower mounted to car canopy on isolated rubber grommets. Morrison Products, Model AA with diffuser and grille, or approved equal.

i. Lighting: Provide minimum average 15 foot-candle illumination at car floor utilizing high output LED fixtures. Provide battery standby power for operation. Provide fixtures with wiring and hookup. Coordinate with emergency lighting requirements. Provide emergency lighting integral with portion of normal car lighting system. Include required transformer.

1) All fixtures shall be above the ceiling and not allow removal without special tools. Fixture replacement shall be able to be performed from within the elevator cab by non-elevator maintenance personnel.

j. Suspended Ceiling: Special design as shown in the Contract Drawings.


F. Operation

1. Simplex Automatic for single elevators, Selective Collective for elevators located in groups.

a. Approved microprocessor-based car and motion control systems as follows including, as a minimum, the features described hereafter:

1) KONE KCM
2) MCE Motion 4000
3) Schindler Miconic
4) Swift Futura
5) Thyssenkrupp TAC 50
6) Smartrise
7) Elevator Controls Corp. Pixel

b. Register service calls on cars from pushbuttons located at each floor and in each car. Slow down, and automatically stop cars at landings corresponding to registered calls. Make stops at successive floors for each direction of travel irrespective of order in which calls are registered.

c. Use easily re-programmable system software.

d. Required Features:

1) Position Sensing: Reset car position when passing or stopping at each landing.
2) Hall Pushbutton Failure: Multiple power sources and separate fusing for pushbutton risers.

3) Duplicate communication link; all individual car computers.

2. Other Items:

a. Load Weighing: Provide means for weighing car passenger load. Design control system to provide dispatching at main floor in advance of normal intervals when car fills to capacity. Provide hall call by-pass when the car is filled to preset percentage of rated capacity and traveling in down direction. (Field adjustment range: 10 percent to 100 percent.)

b. Anti-Nuisance Feature: If car loading relative to weight is not commensurate with registered car calls, cancel car calls. Systems employing either load weighing or door protective device for activation of this feature are acceptable.

c. Independent Service: Provide controls for operation of each car from its pushbuttons only. Close doors by constant pressure on desired destination floor button or door close button. Open doors automatically upon arrival at selected floor.

d. Elevator Remote Disable: During non-revenue hours, public access to and use of the elevators shall be restricted. Control systems shall permit the Link Control Center (LCC) to shut down elevator usage during non-revenue hours and enable operation during revenue hours.

e. Car-to-Street or Lobby Feature: Provide the means for automatic return to the Street or Lobby level. Return car nonstop after answering pre-registered car calls, and park with doors open until the car is returned to normal operation.

f. Firefighters’ Service: Provide equipment and operation in accordance with Code requirements.

g. Automatic Car Stopping Zone: Stop car within 1/4 inch above or below the landing sill. Avoid over-travel or under-travel, and maintain stopping accuracy regardless of load in car, direction of travel, distance between landings, and rope slippage or stretch.

h. Motion Control: Microprocessor based AC variable-voltage, variable frequency with digitally encoded closed-loop velocity feedback suitable for operation specified and capable of providing smooth, comfortable car acceleration, retardation, and dynamic braking. Limit the difference in car speed between full load and no load to not more than plus or minus 3 percent of the Contract speed.

i. Door Operation: Automatically open doors when car arrives at main floor whether car call has been registered or not.

j. Standby Lighting and Alarm: Car mounted battery unit with solid-state charger to operate alarm bell and car emergency lighting. The Battery shall be rechargeable with a minimum five-year life expectancy. Coordinate the location of light fixture with the Resident Engineer. Provide constant-pressure test button in service compartment of car operating panel.
k. Automatic Light and Fan Shut Down: The control system shall evaluate the system activity and automatically turn off the cab lighting and ventilation fan during periods of inactivity. The settings shall be field programmable.

l. Standby Power Transfer: Upon loss of normal power, adequate standby power shall be supplied via the normal electrical feeders to simultaneously start and run all single cars at rated car speed and load.

1) Automatically return cars nonstop to designated floor, open doors for approximately 3.0 seconds, close doors, and park out-of-service. During return operation, car and hall call pushbuttons shall be rendered inoperative. When all cars have returned to the designated floor, all cars shall be designated for automatic operation.

2) Provide separate key-operated selector switch in the firefighters’ control panel.

3) Switch labeled STANDBY POWER OVERRIDE with positions marked AUTO and appropriate car numbers. Key shall be same as that used for firefighters’ Phase I and II switch, key removable in AUTO position only.

4) Switch shall override automatic return and automatic selection functions, and shall cause the manually selected car to operate. Manual selection shall cause car to start and proceed to designated floor and open and close its doors before standby power is transferred to the next selected car.

5) Provide STANDBY POWER indicator lights (one per car) in firefighters’ control panel. Indicator light illuminates only when corresponding car is selected to automatically or manually operate on standby power.

m. Seismic Operations and Equipment

1) Provide design, components and operation in accordance with governing code. Provide dual counterweight derailment sensing wires vertically each side of counterweight the entire height of travel. The counterweight frame shall be equipped with four derailment rings. A dual axis seismic switch shall be provided that will activate at no less than 0.15 times gravity in the vertical or horizontal directions. A minimum of one seismic switch shall be provided per single or group of elevators. Counterweight retainer plates shall be bolted; welded plates are not acceptable.

n. Sump High Water Sensor:

1) Provide sump high water float switch with audible alarm. Switch shall be capable of notifying BMS system when capacity of sump has been exceeded.

o. Ascending Car Overspeed Protective Device

1) Provide a device designed to prevent an ascending elevator from striking the hoistway overhead structure. The device shall decelerate the car with any load up to the rated capacity by applying an emergency brake.
a) The device shall detect an ascending car overspeed condition of not greater than 10 percent higher than the speed that the car governor is set to trip.

b) The device, when activated, shall prevent operation of the car until the device is manually set.

c) The device shall meet the requirements of ASME A17.1 – 2010 Safety Code.

p. Unintended Car Movement Protective Device

1) Provide a device to prevent unintended car movement away from the landing when the hoistway doors are not in the closed and locked position and the car doors are not in the closed position.

a) The device shall prevent such movement in the event of failure of the electric driving machine motor, brake, coupling, shaft or gearing, control system, and any other component upon which the speed of the car depends, except the suspension ropes and the drive sheave of the traction machine.

b) The device, when activated, shall prevent operation of the car until the device is manually reset.

c) The device shall meet the requirements of ASME A17.1 – 2010 Safety Code.

G. Elevator Machine Equipment

1. Arrange equipment in spaces shown on Contract Drawings.

2. Gearless Traction Hoist Machine:

   a. Traction, gearless type with AC induction or P.M.S.M. ACV3F motor, brake, gear, drive shaft, deflector sheave, and gear case mounted in proper alignment on an isolated bedplate. Provide bedplate blocking, secondary or deflector sheave frames and overhead beams/sheaves as required by hoist machine location. Provide all standard equipment. Provide the following optional equipment:

      1) Drip pans
      2) Brake switch
      3) Sheave guard
      4) Machine bedplate
      5) Foundation bolts and pipe spacers
      6) Manual brake release
      7) Rope Gripper Mounting Provisions
      8) VVVF-AC Hoist Motor

3. Solid State Power Conversion and Regulation Unit:
a. Design unit to limit current, suppress noise, and prevent transient voltage feedback into building power supply. Provide internal heat sink cooling fans for the power drive portion of the converter panels. Conform to recommended practice for Emergency and Standby Power Systems for Industrial and Commercial Applications for line harmonics and switching noise.

b. Isolate unit to minimize noise and vibration transmission. Provide isolation transformers, filter networks, and choke inductors.

c. Suppress solid-state converter noises, radio frequency interference, and eliminate regenerative voltage transients induced into the mainline feeders or the building standby power generator.

d. Supplement direct-current power for the operation of hoist machine brake, door operator, dispatch processor, and signal fixtures from separate static power supply.

4. Encoder: Direct drive, solid-state, optical, digital type. Update car position at each floor and automatically restore after power loss.


   a. Compartment: Securely mount all assemblies, power supplies, chassis switches, and relays, on a substantial, self-supporting steel frame. Completely enclose equipment with covers.

   b. Relay Design: Magnet operated with contacts of design and material to ensure maximum conductivity, long life and reliable operation without overheating or excessive wear. Provide wiping action and means to prevent sticking due to fusion. Contacts carrying high inductive currents shall be provided with arc deflectors or suppressors.

   c. Use of SIL (Safety Integrity Level) rated devices for EPD (Electrical Protective Devices) where possible is preferred to traditional positively opened mechanical switches. These devices shall be listed/certified and labeled/marked to a SIL rating in accordance with the applicable requirements of IEC 61508-2 and IEC 61508-3 with a SIL rating equal to or greater than the SIL indicated for the applicable device shown in ASME A17.1.

   d. The detection of a dangerous fault (e.g. with diagnostic tests, proof-tests, or by any other means) in SIL rated electrical/electronic/programmable electronic system (E/E/PES, or commonly referred to as "PES") that can tolerate a single fault shall cause the elevator to revert to a known fail-safe condition. Where necessary, to maintain the integrity of the SIL rated PES and maintain the fail-safe condition prior to a second fault that could lead to a dangerous condition, a manual reset shall be required to remove the SIL rated PES from the fail-safe condition.

   e. Microprocessor-Related Hardware:

      1) Provide built-in noise suppression devices, which provide a high level of noise immunity on all solid-state hardware and devices.

      2) Provide power supplies with noise suppression devices.

      3) Isolate inputs from external devices (such as pushbuttons) with isolation modules.
4) Design control circuits so that one side of power supply is grounded.

5) Safety circuits shall not be affected by accidental grounding of any part of the system.

6) System shall automatically restart when power is restored.

7) System memory shall be retained in the event of power failure or disturbance.

8) Equipment shall operate properly with a 500 Kilohertz to 1300 Megahertz radio frequency signal, transmitted at a power level of not less than 100 watts Effective Radiated Power (ERP) at a distance of 3 feet.

9) Provide equipment with Electro Magnetic Interference (EMI) shielding within FCC guidelines.

f. Wiring: CSA labeled copper for factory wiring. Neatly route all wiring interconnections and securely attach wiring connections to studs or terminals.

g. Provide controller or machine mounted auxiliary, lockable “off” disconnect if mainline disconnect not in sight of controller and hoist machine.

h. Permanently mark components (relays, fuses, and PC boards) with symbols shown on wiring diagrams.

i. Provide controller or machine mounted auxiliary, lockable off, disconnect if mainline disconnect not in sight of controller and machine.

6. Sleeves and Guards: 4-inch steel angle guards around cable or duct slots through floor slabs or grating. Provide rope and smoke guards for sheaves, cables, and cable slots in machine room and secondary levels. Provide wire mesh infill barrier between hoistway and machine room openings.


a. Provide bearing plates, anchors, shelf angles, blocking, and embedments for support and fastening of machine beams or equipment to the building structure.

b. Isolate machine and overhead sheave beams to eliminate noise and vibration transmission to building structure.

c. Provide ladders and platforms with handrails and toeboards for overhead sheave access.

8. Governor: Hoist machine manufacturer’s standard, centrifugal-type, car and counterweight driven, with pull-through jaws and bi-directional electrical shutdown switches. Provide required auxiliary supports for attachment to building structure.

a. Governor shall be remote set/automatic reset type.
9. Vibration Isolation: All elevator equipment provided under this Contract, including power conversion unit, controller and their support, shall be mechanically isolated from the building structure and from electrically induced vibration to minimize the possibility of objectionable noise and vibrations being transmitted to the car, building structure, or occupied areas of building.

10. Sound Isolation:
   a. Noise level relating to elevator equipment and its operation shall not exceed 55 dBA for continuous noise or 62 dBA for intermittent noise in the machine room and cab.
   b. Take all dBA readings 3 feet off the floor and 3 feet from the equipment in machine room.
   c. Take all dBA readings 5 feet off the floor and 1 foot or more from wall in cab.

11. Connection to Remote Monitoring Interface Terminal Cabinet:
   a. Provide conduit and wiring between the elevator controller and the interface terminal cabinet for remote monitoring and control of each car by the Building Management System. See Drawings for Building Management System Elevator Interface Diagram and I/O Points for Typical Equipment
      1) Receive the following dry contact inputs to effect the following control actions for each car.
         a) Phase 1 Recall – Primary (from fire alarm panel).
         b) Phase 1 Recall – Alternate (from fire alarm panel)
         c) Access control permissive.
         d) Elevator Remote Disable.
      2) Provide normally open dry contacts for each of the following status items for each car:
         a) Elevator Warning Alarm
         b) Passenger Alarm Pushbutton
         c) Phase 1 Fire Operation
         d) Phase 2 Fire Operation
         e) Elevator door closed.
         f) Independent Service
         g) Seismic Operation
         h) Elevator at floor (one contact per floor)
         i) Standby Power Operation
b. Provide conduit and wiring between the hoistway sump, high water sensor and the interface terminal cabinet for remote monitoring by the Building Management System.

1) Provide normally open dry contact for each of the following status items for hoistway:

a) Sump High Water Alarm

H. Hoistway Equipment

1. Guide Rails: Minimum 15 pounds per foot or heavier, planed steel T-sections of suitable size and weight for the application, structural support spacing, car weight, counterweight, and seismic reactions, with brackets for attachment to building structure. Provide car rail backing and intermediate counterweight tie brackets to meet Code requirements.

2. Buffers, Car, and Counterweight: Oil type with blocking and support channels. Provide switch on buffer to limit car speed if buffer is compressed. Provide buffer access ladder and platform.

3. Sheaves: Machined grooves with sealed bearings. Provide mounting means to machine beams, machine bedplate, and car and counterweight structural members.

4. Counterweight: Steel frame with metal filler weights, guided by 5-inch roller guide shoes.

5. Counterweight Guard: Metal guard in pit.

6. Governor Rope and Encoder Pit-Tensioning Sheave: Mount sheave and frame on pit floor support frame or guide rail. Provide with guides or pivot point to enable free vertical movement and proper tension of cable/tape.

7. Hoist and Governor Ropes:

a. 8 by 19 or 8 by 25 Seale construction, traction steel type. Fasten with staggered length, adjustable, spring isolated shackles.

b. Governor rope to suit manufacturer’s specification.

8. Terminal Stopping: Provide normal, final and emergency terminal speed limiting devices. Provide ability to bypass final limit while in inspection mode on car to properly access and maintain the overhead sheaves, beams and governor for Elevators. There will be no secondary platforms or access panels provided for service to the overhead area.

9. Copper Electrical Wiring and Wiring Connections:

a. Conductors and Connections: Copper throughout with individual wires coded and connections on identified studs or terminal blocks. Use no splices or similar connections in wiring except at terminal blocks, control compartments, junction boxes, or condulets. Provide 10 percent spare conductors throughout. Run spare wires from car connection points to individual elevator controllers in the machine room.

1) All wiring within hoistway shall be suitable for wet locations.

b. Conduit: Painted or galvanized steel conduit and duct. Conduit size, 1/2 inch minimum. Flexible conduit not to exceed 36 inches in length.
Flexible heavy-duty service cord may be used between fixed car wiring and car door switches for door protective devices.

1) All raceways and wiring mounted on the top of the elevator shall be suitable for wet locations. The routing of the raceways or conduit shall be routed to preclude damage from being stepped on during maintenance. If this is not possible provide steps or other additional protection.

c. Traveling Cables: Type ET flame and moisture-resistant outer cover. Prevent traveling cable from rubbing or chafing against hoistway or equipment within hoistway. Refer to “special elevator equipment” for list for spares to be included in traveling cables.

10. Entrance Equipment:

a. Door Hangers: Two-point hanger roller with neoprene roller surface and suspension with eccentric upthrust roller adjustment.
b. Door Tracks: Bar or formed, cold-drawn removable steel tracks with smooth roller contact surface.
c. Door Interlocks: Operable without retiring cam. Paint interlocks flat black.
d. Door Closers: Spring, spirator, or jamb/strut mounted counterweight type. Design and adjust to ensure the smooth quiet mechanical close of doors.
e. Floor Numbers: Stencil paint 4-inch high floor designations in contrasting color on inside face of hoistway doors at each landing and adjacent to the leading edge of the door.

I. Special Elevator Equipment: The elevators shall accommodate certain communication subsystem equipment which shall be provided. This equipment and its appurtenances shall be built into the elevator at the factory, unless noted otherwise.

1. CCTV Cameras: Provide and Install 2 cameras for each elevator

a. Axis P3364 or approved equal
b. Imaging device: 1/3 inch color CCD 3-9 mm, vari-focal, auto iris lens
c. Ability to control and monitor video over IP network
d. Supported protocols: TCP/IP, UDP/IP (unicast, multicast IGMP), UPnP, DNS, DHCP, RTP, NTP
e. Supported video resolutions: 4CIF, 2CIF, CIF, QCIF
f. Digital compression: MJPEG, MPEG-4
g. Web user viewing interface with up to 5 additional simultaneous users
h. Cameras to support low-light capability
i. Camera shall be connected by CAT6 to an Ethernet PoE switch located in a Contractor supplied enclosure attached to the elevator cab.

2. CCTV Camera Enclosure: Provide and Install for each CCTV Camera.
a. Install CCTV cameras with protective housings.
b. Mini-dome with integrated camera and lens
c. Tamper resistant hardware
d. Rugged, high-impact, puncture-proof, opaque (smoked) dome plastic
e. NEMA 4X and IP 66
f. Input voltage: 18 - 30VAC, 24 VAC nominal
g. Above ceiling dimensions: 2 inches high x 3.5 inches wide, nominal
h. Below ceiling dimensions: 2.5 inches high x 5.5 inches wide, nominal
i. Dome diameter: 3.75 inches, nominal
j. Cable: RJ45-10 connector for 100Base-TX Ethernet

   a. On activation, system dials preprogrammed number of monitoring station and identifies elevator location to monitoring station.
   b. System provides two-way voice communication without using a handset and provides visible signals that indicate when system has been activated and when monitoring station has responded.
   c. System is contained in flush-mounted cabinet, with identification, and instructions for use.

4. PA Speakers:
   a. Provide and install an 8 ohm public address speaker in the car canopy and connect via speaker cabling to Contractor provided PA terminals in the interface terminal cabinet in the Elevator Machine Room.
   b. Provide and install Atlas UKT speakers, 95-8-7 backbox, FAMT-6 adapter plate and 60-8A round satin aluminum finish grill or approved equal.

5. Radio Antenna: Provide mounting provisions for Commprod antenna in the elevator cab ceiling. Antenna to be provided by Emergency Radio Contractor. Provide cabling from the car to the interface terminal cabinet in the machine room.

6. For elevators requiring access to non-public floors: Provide and install Lenel 2210 door controller mounted in the NEMA 4X enclosure

7. For elevators requiring access to non-public floors: Provide and install HID iClass R40 card reader in the elevator cab.

8. ST-provided PoE Ethernet Switch
   a. Install ST-provided PoE Ethernet switches.
b. One switch shall be installed in the elevator cab and the other in the elevator machine room.

c. Minimum of 8 ports.

d. At least one fiber port for switch to switch connection.

e. Connect door controller and cameras to the Ethernet switch via CAT6 cable.

f. The Ethernet switch in the elevator shall be connected to the Ethernet switch in the elevator machine room via Contractor provided fiber optic cable in the travelling cable.

g. Power for the switch shall be provided from the station’s Communications UPS power.

h. Configuration settings from the Ethernet switch per Sound Transit IT department.

9. Elevator Cab Enclosure: provide a NEMA 4X enclosure, attached to the elevator cab, accessible from inside the cab, sized to install the door controller, Ethernet switch, and fiber distribution panel.

a. Layout of devices shall provide easy maintenance access.

b. Provide elevator power to all powered devices in the enclosure.

10. Communications Cabling and Wiring: Provide and install communications systems wiring within the traveling cable from car device to the elevator controller cabinet or the Interface Terminal Cabinet located in elevator machine room. Land wiring on terminal blocks or connectors specifically made for the intended use. Provide and install conduit between elevator controller and the Interface Terminal Cabinet.

a. All cabling to be plenum rated and shall be as follows:

b. Elevator cab PoE ethernet switch to elevator machine room ethernet switch: 6-strand plastic (multi-mode), or glass (single mode) fiber optic cable. Terminate all strands of the fiber in an FDP with LC connectors on both ends. Provide patch cords from the FDP to the switches.

The fiber cable provided and installed shall be rated to withstand the repeated movement associated with the duty cycle of the elevator (to be noted in product data submittal) while also meeting the Sound Transit performance criteria noted below over the expected life of the traveling cables.

1) Fiber Optic Performance Criteria

a) Effective Minimum Bitrate (R) is two times the bandwidth

\[(\Delta f)\cdot R \left[\frac{Mbps}{Hz}\right] = 2 \cdot \Delta f [MHz]\]

b) Attenuation Guidelines:
Glass Fiber

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Attenuation Rate (db/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1550</td>
<td>0.25</td>
</tr>
<tr>
<td>1625</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Max Loss Budget Calculation

Max Loss Budget [dB] = \((\text{Length}[\text{km}] \times \text{Attenuation Rate}) + (\text{Connector pairs} \times 0.25 \text{ dB}) + (\text{Number of splices} \times 0.25 \text{ dB})\)

Plastic Fiber

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Attenuation Rate (db/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>650</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Max Loss Budget Calculation

Max Loss Budget [dB] = \((\text{Length}[\text{m}] \times \text{Attenuation Rate}) + (\text{Connector pairs} \times 2.5 \text{ dB}) + (\text{Number of splices} \times 2.5 \text{ dB})\)

d. Testing Requirements

1) Minimum Effective Bitrate of 2.5 Mb/sec.

2) Losses determined from OTDR testing within the calculated Max Loss Budget.

Example: 100 meter Elevator Traveling Cable Fiber Optic Criteria

<table>
<thead>
<tr>
<th>Fiber Material</th>
<th>Effective Minimum Bitrate</th>
<th>dB Max. Loss Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>2.5 Mb/sec</td>
<td>25.70 dB</td>
</tr>
<tr>
<td>Glass</td>
<td>2.5 Mb/sec</td>
<td>1.73 dB</td>
</tr>
</tbody>
</table>

3) Installing contractor shall demonstrate fiber optic performance via witnessed OTDR dB attenuation testing conducted in accordance with TIA-568-C.0 Compliant Fiber Optic Test Procedures. Fiber cable must meet the above performance upon initial testing and throughout the full life of the traveling cables.

4) Installing contractor to conduct testing for bandwidth to determine effective minimum bit rate over the fully connected
traveling cable between nearest elevator machine room network connection switch and cab network switch. Regardless of traveling cable length, the Effective Minimum Bitrate of 2.5Mb/sec is required.

5) Test results shall be provided to Sound Transit under Submittals.

d. Paging speaker: One copper pair 16 AWG

e. Radio Antenna: One super flex 75-ohm coaxial cable

f. Wiegand cabling from the door controller to the access card reader.

g. CAT6:

1) Elevator cab: from the cameras and door controller to the PoE Ethernet switch.

2) Elevator machine room: from the PoE Ethernet switch to RJ45 jacks on the interface terminal cabinet.

h. Instrumentation: Minimum 6 shielded twisted pairs; minimum #18 gauge instrumentation cable

i. Provide four pairs of spare shielded communication wires in addition to those required to connect specified items. Tag spares in machine room.

2.04 COMPONENTS

A. Hoistway Entrances

1. Complete entrances bearing UL fire labels.

2. Frames: Stainless steel at all floors. Standard bolted head to jamb connection assemblies fabricated from not less than 14-gauge material. Permanently attach rear mounted Arabic floor designation plates, centerline at 60 inches above finished floor, on both sides of jambs existing. Provide main egress landing plates with Star designation. Braille indications shall be below Arabic floor designation.


a. Provide leading edge of side-opening doors with rubber astragals. Provide a minimum of three gibes per panel; one at leading edge, one at trailing edge and one at center of leaf with gibes in the sill groove entire length of travel.

b. Provide leading edge of center-opening doors with rubber astragals. Provide a minimum of three gibes per panel; one at leading edge, one at trailing edge and one at center of leaf with gibes in the sill groove entire length of travel.

1) Gibs shall be roller type, with three rollers per gib, to reduce kinetic friction effects during hoistway pressure differential events.

c. Elevators with Rated Shaft: Provide safety glass vision panel approximately 4 inches by 20 inches in one panel.
d. Elevators without Rated Shaft: Provide 9/16 inch thick laminated tempered glass approximately 16 inches by 72 inches in each door panel.

4. Sight Guards: 14-gauge, same material and finish as hoistway entrance door panels. Construct without sharp edges.


6. Sill Supports: Structural or formed steel designed to support door sill based upon car loading classification. Grout under the sill. Five-inch by 5-inch by 1/2-inch cold-rolled structural steel angle, extend full width of hoistway. Fasten to building structure at maximum 18 inches on center. Refer to Contract Drawings for additional details.


8. Struts and Headers: Provide for vertical support of entrances and related material.


B. Hall Control Stations

1. Pushbuttons: Provide one riser with flush-mounted faceplates. Include pushbuttons for each direction of travel, which illuminate to indicate call registration. Include approved engraved message and pictorial representation prohibiting use of elevator during fire or other emergency situation as part of faceplate. Pushbutton design shall match car operating panel pushbuttons. Provide vandal resistant pushbutton and light assemblies. Circuit boards for hall call station switches shall be conformal coated.

2. Hoistway Door Unlocking Device: Provide unlocking device with locking escutcheon plug in door panel at all floors with finish to match adjacent surface.


4. Faceplate Material and Finish:
   c. Lobby Position Indicator: Non-directional stainless steel.
   d. Hall Pushbutton Station: Non-directional stainless steel.
   e. Hoistway Access Switch: Non-directional stainless steel.

C. Signals

1. Hall Lantern: Provide at each entrance to indicate travel direction of arriving car. Locate as detailed on Contract Drawings. Illuminate up or down lights and sound tone twice for down direction travel prior to car arrival at floor. Sound level to be adjustable from 20 to 80 dBA measured at 5 feet in front of hall pushbutton and 3 feet off floor. Illuminate light until the car doors start to close. Provide advanced hall lantern notification to comply with ADA hall call notification time. Minimum 2
and 1/2 inches in the smallest dimension, arrow lenses with faceplates. Provide vandal resistant lantern and light assemblies consisting of series of dots or lines for maximum visibility.

2. Car Position Indicator: Alpha-numeric digital indicator containing floor designations and direction arrows a minimum of 1/2 inch high to indicate floor served and direction of car travel. Locate fixture in each car operating panel. When a car leaves or passes a floor, illuminate indication representing position of car in hoistway. Illuminate proper direction arrow to indicate direction of travel. Provide vandal resistant indicator and light assemblies.

3. Lobby Position Indicator: Alpha-numeric digital indicator containing floor designations and direction arrows a minimum of 1/2 inch high to indicate floor served and direction of car travel. Locate fixture integral with hall lanterns at Plaza level. When a car leaves or passes a floor, illuminate indication representing position of car in hoistway. Illuminate proper direction arrow to indicate direction of travel. Provide vandal resistant indicator and light assemblies.

4. Floor Passing Tone: Provide an audible tone of no less than 20 dBA and frequency of no higher than 1500 Hertz, to sound as the car passes or stops at a floor served.

5. Voice Synthesizer: Provide electronic device with easily re-programmable message and voice to announce car direction, floor, and emergency exiting instructions.

6. Card reader override: Provide conduit and wiring to control panel. Fixtures shall be located as directed by the Resident Engineer. Coordinate size and location.

7. Fire Fighters’ Control Panel: Locate in the station’s Fire Command Center Room. Furnish and install panel and all applicable wiring from each elevator to the fire panel. All supplied conductors shall conform to the requirements of NFPA 130. Associated conduit to be provided by Electrical. Fixture faceplate, No. 4 brushed finish stainless steel, including the following features:

   a. Car position and direction indicator (digital-readout or color SVGA display type). Identify position indicator with car number.

   b. Indicator showing operating status of car.

   c. Wiring to panel. Conduit from closest elevator hoistway of each group by others.

   d. Manual car standby power selection switch and power status indicator.

   e. Two position fire fighter’s emergency return switches and indicators with engraved instructions filled with red epoxy paint.

8. Communication Failure: Provide phone line communication failure indicator light and reset keyswitch integral mounted within hall control station located at the primary phase 1 recall landing.
PART 3 - EXECUTION

3.01 EXAMINATION
A. Before installing equipment, examine hoistway and machine room areas. Verify that no irregularities exist that affect execution of work specified. Hoistway and pit to be evaluated and confirmed as sealed and watertight prior to commencing installation of elevator equipment.
B. Do not proceed with installation until work in place conforms to Contract requirements.

3.02 INSTALLATION
A. Install all equipment in accordance with Manufacturer's instructions, referenced Codes, these Contract Specifications and approved submittals.
B. Install machine room equipment with clearances in accordance with referenced Codes and these Contract Specifications.
C. Install all equipment so it may be easily removed for maintenance and repair.
D. Install all equipment for ease of maintenance.
E. Install all equipment to afford maximum accessibility, safety, and continuity of operation.
F. Remove oil, grease, scale, and other foreign matter from the following equipment and apply one coat of field-applied machinery enamel.
   1. All exposed equipment and metal work installed as part of this work that does not have architectural finish.
   3. Neatly touch up damaged factory-painted surfaces with original paint and color. Protect machine-finish surfaces against corrosion.

3.03 FIELD QUALITY CONTROL
A. Work at jobsite will be checked during course of installation. Full cooperation with reviewing personnel is mandatory. Accomplish corrective work required prior to performing further installation.
B. Have Code Authority acceptance inspection performed and complete corrective work.

3.04 ADJUSTING
A. Install rails plumb and align vertically with tolerance of 1/16 inch in 100 feet. Secure joints without gaps and file any irregularities to a smooth surface.
B. Static balance car to equalize pressure of guide shoes on guide rails.
C. Lubricate all equipment in accordance with Manufacturer's instructions.
D. Adjust motors, power conversion unit, brake, controllers, leveling switches, limit switches, stopping switches, door operators, interlocks, and safety devices to achieve required performance levels.
3.05 CLEANING
A. Keep work areas orderly and free from debris during progress of Contract. Remove packaging materials on a daily basis.
B. Remove all loose materials and filings resulting from work.
C. Clean machine room equipment and floor.
D. Clean hoistways, car, car enclosure, entrances, and operating and signal fixtures per submitted procedures as required to meet sign off requirements of L&I.

3.06 DEMONSTRATION
A. General: Furnish labor, materials, and equipment necessary for tests. Notify the Resident Engineer five days in advance when ready for final review of unit or group. Acceptance of installation will be made only after all field-quality control reviews have been completed, identified deficiencies have been corrected, all Sound Transit’s information and certificates have been received, and the following items have been completed to satisfaction of Sound Transit:

1. Workmanship and equipment comply with these Contract Specifications.
2. Contract speed, capacity, floor-to-floor, and door performance comply with these Contract Specifications.
3. Performance of following are satisfactory:
   a. Starting, accelerating, running
   b. Decelerating, stopping accuracy
   c. Door operation and closing force
   d. Equipment noise levels
   e. Lighting levels
   f. Signal fixture utility
   g. Overall ride quality
   h. Performance of door control devices
   i. Operations of special security operation and floor lock-off provisions.
   j. Fiber optic cabling within travelling cables performs to Sound Transit Elevator Traveling Cable Fiber Optic Performance Criteria
   k. Demonstrate CCTV Camera image on computer connected to data cable to Interface Terminal Cabinet
   l. Demonstrate the PA system works by connecting to an amp and broadcasting voice over speaker.
   m. Demonstrate phone installation by dialing designated ST control center.
   n. Demonstrate each monitoring and control signal to Building Management System at Interface Terminal Cabinet.
4. Test Results:
a. In all test conditions, obtain specified speed, performance times, stopping accuracy without re-leveling, and ride quality to satisfaction of the Resident Engineer,

b. Temperature rise in motor windings limited to 120 degrees F above ambient. A full-capacity, 1-hour running test, stopping at each floor for 10 seconds in up and down directions, may be required.

B. Performance Guarantee: Should tests reveal defects, poor workmanship, variance or noncompliance with requirements of specified Codes and/or ordinances, or variance or noncompliance with the requirements of these Specifications, complete corrective work to satisfaction of Resident Engineer at no cost:

1. Replace equipment that does not meet Code or these Specifications requirements.
2. Perform work and furnish labor, materials, and equipment necessary to meet specified operation and performance.
3. Perform and assume cost for retesting required by Governing Code, Authority, and Sound Transit to verify specified operation and/or performance.

C. Field Review Scheduling: Schedule progress and final equipment reviews with the Resident Engineer. Reply promptly, in writing, to corrective work indicated on the Resident Engineer’s progress and/or final review reports, indicating status, schedule for completion, and questions.

3.07 TRAINING

A. Provide orientation and training to familiarize Sound Transit operations personnel with the features and operation of the elevator.

1. Include step-by-step instructions for elevator operations, controls and features, including procedures for locking down elevators when not in service.
2. Training shall include complete familiarization of the elevator and elevator machine room, including components installed within the machine room.

3.08 COMMISSIONING

A. Refer to specifications Section 14 08 00 Commissioning of Conveying Equipment for further requirements pertaining to the work in this section.

END OF SECTION
STANDARD SPECIFICATIONS

SECTION 14 24 00
HYDRAULIC ELEVATORS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing and providing Maintenance for hydraulic passenger elevators as specified and detailed in the Contract Drawings.

B. Related work provided under other sections

1. Hoistway and Pit
   a. Clear, plumb, and substantially flush hoistway with variations not to exceed 1 inch at any point.
   b. Bevel cants not less than 75 degrees with the horizontal on any rear or sidewall ledges and beams that project or recess 2 inches or more into the hoistway. Not required on hoistway divider beams.
   c. Supports at each floor for car and counterweight guide rail fastening. Intermediate support when heights exceed 14 feet 0 inch. Building supports not to deflect more than 1/8 inch under normal conditions and 1/4 inch under seismic conditions.
   d. Installation of guide rail bracket supports in concrete. Inserts or embeds, if used, will be furnished under this Section.
   e. Wall blockouts and fire rated backing for control and signal fixture boxes that penetrate walls.
   f. Cutting and patching walls and floors. Finished floors slope away from elevator doors.
   g. Opening in hoistway wall or pit wall for hydraulic piping. Trench and backfill underground piping.
   h. Erect front hoistway wall after elevator entrances are installed.
   i. Grout around hoistway entrances and sills.
   j. Provide pit access ladder for each elevator.
   k. Provide structural support for car buffer impact loads, guide rail loads, and cylinder loads.
   l. Waterproof pit. Dry sump with flush grate.
   m. Protect open hoistways and entrances during construction in accordance with OSHA Regulations.
n. Protect car enclosure, hoistway entrance assemblies, and special metal finishes from damage after installation.

o. Hoistway venting or pressurization to prevent accumulation of smoke and gas as required by Local Building Code.

p. Seal fireproofing to prevent flaking.

2. Machine Room
   a. Provide enclosure with access.
   b. Provide self closing and locking access door with panic door hardware.
   c. Provide ventilation, air conditioning and heating as required. Maintain minimum temperature of 55 degrees F, maximum 90 degrees F. Maintain maximum 80 percent relative humidity, non-condensing.
   d. Paint walls, ceiling, and floor.
   e. Provide class "ABC" fire extinguisher.
   f. Seal fireproofing to prevent flaking.
   g. Provide fire sprinklers where required.

3. Electrical Service, Conductors and Devices
   a. Provide lighting and Ground Fault Circuit Interrupter (GFCI) convenience outlets in pit and machine room.
   b. Provide conduit from the closest hoistway of each elevator group or single elevator to the firefighters’ control room and communications distribution cabinet. Coordinate size, number, and location of conduits.
   c. Provide three-phase mainline copper power feeder to terminals of each elevator controller in the machine room with protected, lockable “OPEN,” disconnect with auxiliary contacts to allow electrical interlock with battery power lowering unit.
   d. Provide single-phase copper power feeder to each elevator controller for car lighting and exhaust blower with individual protected, lockable “OFF,” disconnect switch located in machine room.
   e. Provide single-phase copper power feeder to each elevator controller for tank heater, cylinder heat trace system and oil cooler system (min. 20 amps) with individual protected, lockable “OFF,” disconnect switch located in machine room.
   f. Provide products-of-combustion sensor (NFPA 72, Chapter 5-3) in each elevator lobby, for each group of elevators or for single elevator and machine room to initiate firefighters’ return feature. Provide detector at top of hoistway if sprinklered. Provide means for service access from outside the hoistway. Provide sensor signal wiring from hoistway or machine room connection point to elevator controller terminals.
   g. Provide temporary power and illumination to install, test, and adjust elevator equipment.
h. Provide means to manually and automatically disconnect power to affected elevator pump unit and controller prior to activation of machine room overhead fire sprinkler system, and/or hoistway overhead fire sprinkler system. Manual shut-off means shall be located outside bounds of machine room.

i. When sprinklers are provided in the hoistway, all electrical equipment, except seismic protective devices, located less than 4 feet above the pit floor shall be identified for use in wet locations (NFPA 70).

j. Provide power feeder to elevator intercom amplifier located in the elevator machine room.

k. Provide power feeder to each elevator controller in machine room for elevator car heating and air conditioning unit.

C. Equipment furnished by Sound Transit, installed under this Section:

1. Network Switch
2. Production of combustion sensor

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. American National Standards Institute (ANSI)
   a. ANSI Z97.1 For Safety Glazing Materials Used in Buildings – Safety Performance Specifications and Methods of Test

2. American Society of Mechanical Engineers (ASME)
   a. ASME A17.1 Safety Code for Elevators and Escalators Includes Requirements for Elevators, Escalators, Dumbwaiters, Moving Walks, Material Lifts, and Dumbwaiters with Automatic Transfer Devices
   c. ASME A17.5 Elevator and Escalator Electrical Equipment

3. ASTM International (ASTM)
   a. ASTM A36/A36M Standard Specification for Carbon Structural Steel
   b. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
e. ASTM A1008/A1008M Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

f. ASTM A1011/A1011M Standard Specifications for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

g. ASTM B151 (B151M) Standard Specification for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar

h. ASTM B209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

i. ASTM B221 Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles and Tubes

j. ASTM B418 Standard Specification for Cast and Wrought Galvanic Zinc Anodes

4. Americans with Disabilities Act of 1990 (ADA)

5. Consumer Product and Safety Commission (CPSC)

6. Federal Standard and NAAMM nomenclature

   a. IBC Chapter 30 Elevators and Conveying Systems

8. Institute of Electrical and Electronics Engineers, Inc. (IEEE)
   a. IEEE 446 Emergency and Standby Power Systems for Industrial and Commercial Applications

9. Telecommunications Industry Association (TIA)
   a. TIA-568-C.0 Generic Telecommunications Cabling for Customer Premises

10. National Fire Protection Association (NFPA)
    a. NFPA 70 National Electrical Code
    b. NFPA 72 National Fire Alarm and Signaling Code
    d. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

11. Occupational Safety & Health Administration (OSHA)
    a. 29 CFR Part 1926, Safety and Health Regulations for Construction
12. The Society for Protective Coatings (SSPC)  
a. SSPC SP 6 Commercial Blast Cleaning  

13. Seattle Building Code (SBC) – Applicable to Projects Located Within Seattle  
a. SBC Chapter 30 Elevators and Conveying Systems  

14. Washington Administrative Code (WAC)  
a. Title 296: Department of Labor and Industries; Chapter 296-96: Safety Regulations and Fees for all Elevators, Dumbwaiters, Escalators, and Other Conveyances  

15. American Welding Society, Inc. (AWS)  
a. AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination  
b. AWS D1.1/D1.1M Structural Welding Code – Steel  

16. International Standards Organization (ISO)  
a. ISO 281/1-1997  

1.03 DEFINITIONS  
A. Terms used are defined in the latest edition of the Safety Code for Elevators and Escalators, ASME A17.1.  
B. Reference to a device or a part of the equipment applies to the number of devices or parts required to complete the installation.  

1.04 SUBMITTALS  
A. Pre-revenue Warranty Maintenance Plan  
1. Submit a detailed Pre-revenue Warranty Maintenance Plan.  

B. Shop Drawings: Scaled and Fully Dimensioned Layout that includes plans of pit, hoistway, and machine room indicating equipment arrangement, elevation section of hoistway, details of car enclosures, hoistway entrances, and car/hall signal fixtures.  
1. Indicate equipment lists, reactions, and design information on layouts include heat dissipation requirements for machine room and hoist beam load requirements.  
2. Power Confirmation Sheets: Include motor horsepower, code letter, starting current, full load running current, and demand factor for applicable motors.  
3. Complete control and schematic wiring diagram of the elevator system and subsystems.  
4. Elevator controller, including manufacturer’s technical data and product data, and interface hardware and software requirements.  
5. Within 60 days after Notice to Proceed and before beginning equipment fabrication, submit shop drawings and required material for review.
C. Finish Material: Submit 3-inch by 12-inch samples of actual finished material for review of color, pattern, and texture by Resident Engineer. Compliance with other requirements is the exclusive responsibility of the Contractor. Include signal fixtures, lights, graphics, Braille plates, and mounting provisions.

D. The Contractor shall submit material safety data and product data sheets for all products used by the contractor at the site or which may need to be replaced or added to by the maintenance personnel. Such products include but are not limited to greases, oils and paint. The sheets shall have an index listing each product along with application method, approximate quantity required of the product and the component the product is associated with.

E. Testing Submittals
   1. Submit fiber optic performance test procedure and results.

F. Product Data for Special Elevator Equipment: Submit product catalogs for speakers, cameras, intercom/emergency telephone, Ethernet switch, traveling cable data cables, card reader and door controllers.

G. Operation and Maintenance Manuals
   1. In addition to the requirements stated elsewhere in the Contract Documents, include the following as minimums:
      a. Printed Instructions: Three sets of neatly bound instructions explaining all operating features.
      b. Complete installation, maintenance, adjustment, removal, and testing instructions and procedures for all elevator equipment and components. All instructions shall be at the adjuster’s level and specific to the equipment installed.
         1) Include inspection and maintenance standards including wear limits, settings and tolerances.
      c. Wiring Diagrams: Include a complete set within each Operation and Maintenance Manual, as well as three individually printed and bound complete sets, of as-installed straight-line wiring diagrams showing the electrical connections of all equipment and all modifications to control circuits. Furnish a legend sheet with each set of drawings to provide the following information:
         1) Name and symbol of each relay, switch, or other apparatus.
         2) Location on drawings, drawing sheet number and area, and location of all contacts.
         3) Location of apparatus, whether on controller or on car.
         4) Sequence of operation of apparatus connected with each elevator.
      d. Complete software documentation for all installed equipment, including software updates and or revisions during the progress of the Work.
      e. Lubricating instructions and schedule, including recommended grade of lubricants.
f. Hoistway cleaning procedures required to meet sign off requirements of L&I.

g. List of Special Tools required for inspection, adjustment, maintenance, repair and testing.

h. List of recommended spare parts and stock quantities for routine maintenance of the equipment. Include a list of spare parts considered critical and for which long lead time frames for acquisition would result in extended equipment down-time.

i. Parts Catalog: Complete parts catalogs listing all replaceable parts including Manufacturer’s identifying numbers, current unit price and ordering instructions. Include the complete parts catalog in each Operation and Maintenance Manual, as well as three separate complete printed sets.

j. The Operation and Maintenance Manual shall contain only information related to the equipment installed. Generic information not relevant to the installed equipment shall not be included.

H. Special Tools

1. Provide a complete set of special tools and instruments necessary for troubleshooting and making all adjustments on every part of the elevator installation. Any tools that are designed specifically for tasks associated with elevator inspection, maintenance and repair or that are required for these tasks, are special tools.

2. Diagnostic Equipment: Provide all diagnostic test devices complete with instructions, access codes, adjusters’ manuals and set-up manuals for adjustment, diagnosis and troubleshooting of elevator system, and performance of routine safety tests.

3. Storage cabinet: Provide and install a lockable metal cabinet in each elevator machine room of suitable size for the storage of special tools and necessary spare parts. Cabinet shall be mounted on legs or a pedestal a minimum of 4 inches off the floor. Cabinet to be keyed to Sound Transit standard keying system.

I. Four sets of neatly tagged keys for all switches and control features properly tagged and marked.

1.05 QUALITY ASSURANCE

A. Comply with most stringent applicable provisions of the Code or Authority specified in Article 1.02, herein, including revisions and changes in effect on date of these Contract Specifications:

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver material in Manufacturer’s original, unopened protective packaging.

B. Store material in original protective packaging. Prevent soiling, physical damage, or moisture damage.

C. Protect equipment and exposed finishes from damage and stains during transportation, erection, and construction.
1.07 MAINTENANCE

A. Pre-revenue Warranty Maintenance:

1. Provide full service Warranty Maintenance as described in this section. This period shall commence upon installation and extend to the start of Revenue Service.

   a. Full service maintenance shall include standard monthly maintenance, replacement parts, and annual testing.

2. Provide preventive maintenance as recommended by the manufacturer and in accordance with all applicable codes, during normal working hours. Systematically examine, adjust, clean, and lubricate equipment, parts, components, and subsystems. Repair or replace defective parts using parts produced by the manufacturer of installed equipment. Maintain elevator machine room, hoistway, and pit in clean condition.

3. Defective is defined to include, but not to be limited to; operation or control system failures, performance below required minimum, excessive wear, unusual deterioration or aging of materials or finishes, unsafe conditions, the need for excessive maintenance, abnormal noise or vibration, and similar unsatisfactory conditions.

4. Exercise each elevator during monthly maintenance visits. Exercising of equipment shall consist of continuous operation through entire run of hoistway for one hour. Exercise equipment as necessary to meet a minimum of 150 hours of run time in the first year.

5. All warranty and maintenance work shall be performed by a company that has a current code compliant Maintenance Control Program (MCP) on file with L & I. Warranty maintenance shall meet the MCP criteria as outlined in ASME A17.1 as well as all manufacturer’s recommended maintenance.

6. Equipment Manufacturer is responsible for upgrades and revisions of software and documentation of associated revision to the Operations and Maintenance Manual.

7. The Contractor shall document all maintenance and transmit maintenance records to Sound Transit.

B. Extended Warranty Maintenance:

1. Provide Extended Warranty Maintenance for a five year period commencing at the start of Revenue Service, per Appendix A “Extended Maintenance Services Scope of Work” and as generally described below.

2. Provide full service preventive maintenance as recommended by the manufacturer and in accordance with all applicable codes, and 24 hour emergency callback service. Systematically examine, adjust, clean, and lubricate equipment. Repair or replace parts as necessary using parts produced by the manufacturer of installed equipment. Maintain elevator machine room, hoistway, and pit in clean condition.

3. Removal of units from beneficial usage for maintenance purposes shall be coordinated with and approved by Sound Transit, unless removal is necessitated for emergency repair or adjustment. Normal preventive maintenance service shall be performed during off-peak operating hours.
4. All units shall be available for use an average of 98.7% of property hours of operation over each three-month period during Extended Warranty Maintenance service. This includes allowance for equipment out of service time as the result of callbacks, scheduled preventive maintenance, and repairs. Contractor's failure to meet this unit availability provision for two consecutive three-month periods for any single elevator or escalator, or group of units, shall trigger an automatic maintenance audit by Sound Transit. Contractor agrees to expeditiously take corrective action in regard to identified deficiencies. Further, Contractor acknowledges Sound Transit's right to pass cost of said audit to Contractor.

5. All warranty and maintenance work shall be performed by a company that has a current code compliant Maintenance Control Program (MCP) on file with L & I.

6. Equipment Manufacturer is responsible for upgrades and revisions of software and documentation of associated revision to the Operations and Maintenance Manual.

1.08 PERMIT, TEST AND INSPECTION

A. Obtain and pay for permit, license, and inspection fee necessary to complete the installation. Installation will be considered complete when the governing authority of Washington State Department of Labor and Industries has issued a permanent operating permit for each elevator.

B. Perform tests required by the elevator Section of the Washington State Department of Labor and Industries. Perform tests in accordance with procedures described in ASME A17.2.1 inspector's manual for Electric Elevators and as required by the authorities having jurisdiction in the presence of the Resident Engineer.

C. Contractor is not relieved from furnishing and installing work shown or specified which may be beyond requirements of ordinances, laws, regulations or codes.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Approved Manufacturers

1. Hydraulic Installers: KONE, Otis, Schindler, Thyssen Krupp or approved equal.


3. Control Manufacturers: Manufacturers standard controls (non-proprietary), MCE, and Swift/CEC or approved equal.


5. Hoistway Entrance: Brice-Southern, Hauenstein & Burmeister, KONE, Otis, Schindler, Thyssen Krupp, Tyler or approved equal.

2.02 MATERIALS

A. Steel
1. **Sheet Steel (Furniture Steel for Exposed Work):** Stretcher leveled, cold rolled, commercial quality carbon steel, complying with ASTM A1008, matte finish.

2. **Sheet Steel (for Unexposed Work):** Hot rolled, commercial quality carbon steel, pickled and oiled, complying with ASTM A568 and A1011.

3. **Structural Steel Shapes and Plates:** ASTM A36.

**B. Stainless Steel**
- Type 316 complying with ASTM A167, with standard tempers and hardness required for fabrication, strength, and durability. Apply mechanical finish on fabricated work in the locations shown or specified (Federal Standard and NAAMM nomenclature) with texture and reflectivity required to match Resident Engineer’s sample. Protect with adhesive-paper covering.
  1. Non-directional orbital uniform finish: 80 grit orbital sanding over standard mill plate or shape to produce a uniform non-directional satin finish with 90 percent of mill marks removed to match Resident Engineer’s visual sample.

**C. Aluminum**
- Extrusions conforming to ASTM B221; sheet and plate conforming to ASTM B209.

**D. Nickel Silver**
- Extrusions conforming to ASTM B151/151M.

**E. Paint**
- Clean exposed metal parts and assemblies of oil, grease, scale, and other foreign matter and factory paint one shop coat of rust resistant primer. After erection, provide one finish coat of industrial enamel paint. Galvanized metal need not be painted.

**F. Prime Finish**
- Clean all metal surfaces receiving baked enamel paint finish of oil, grease, and scale. Apply one coat of rust resistant primer followed by a filler coat over uneven surfaces. Sand smooth and apply final coat of primer.

**G. Baked Enamel Finish**
- Prime finish in accordance with Article 2.02F. Apply and bake three additional coats of enamel in the selected solid color.

**H. Glass**
- Laminated safety glass, minimum 9/16 inch thick, conforming to ANSI Z97.1 and CPSC 16 CFR Part 1201.

### 2.03 EQUIPMENT

**A. Equipment shall be the same for all contracts except where specifically noted. Where variations occur, each contract shall be specified separately.**

**B. Elevators**

1. **Number:**
   - As specified and as detailed on Contract Drawings

2. **Capacity and Loading Classification:**
   - As specified and as detailed on Contract Drawings

3. **Speed:** 125 feet per minute

4. **Operational Control:** Selective collective, microprocessor based system

5. **Motor Control:** Single speed AC with SCR soft start with closed transition

6. **Power Characteristics:** 480 Volts, 3 Phase, 60 Hertz
7. Stops and Openings: As specified and as detailed on Contract Drawings
8. Floors Served: As specified and as detailed on Contract Drawings
9. Travel: As specified and as detailed on Contract Drawings
10. Minimum Clear Inside Car:
    a. Geometry Type A: 5 feet 8 inches wide by 7 feet 10 inches deep
    b. Geometry Type B: 7 feet 8 inches wide by 5 feet 3 inches deep
11. Entrance Size: 4 feet 0 inches wide by 7 feet 0 inch high
12. Entrance Type: As detailed in contract drawings.
13. Door Operation: High-speed, heavy duty, master door operator, minimum opening speed 2.5 feet per second
14. Door Protection: Infrared, full screen device, with differential timing and nudging and interrupted beam time
15. Machine: Hydraulic pump
16. Hydraulic Type: Dual telescope plungers
17. Machine Room: As specified and as detailed on Contract Drawings
18. Guide Rails: Planed steel tees
20. Car Enclosure: As specified and as detailed on Contract Drawings Car ceiling height of 8 feet.
   a. Hall buttons and control devices shall be NEMA 4.
23. Position Indicator: Dual digital with direction arrow.
24. Hall Lanterns: At all floors with volume adjustable electronic chime or tone. Sound twice for down direction. Vandal resistant.
   a. Hall lanterns shall be NEMA 4 enclosures at all locations.
25. Hoistway wiring, conduit and enclosures shall be rated for wet locations.
26. Additional Features
   a. Car roller guides
   b. Car top inspection station
   c. Guardrails at car top to meet code requirements for safety.
   d. Firefighters’ service, including alternate floor return feature
e. Battery pack standby power provision
f. Accessibility and emergency medical services access and signage
g. Hinged car return panels arranged for integral car operating panels
h. Hoistway access switches
i. Hoistway door unlocking device. All floors with locking escutcheon plugs.
j. Independent service feature
k. Platform isolation – jack to bolster connection(s)
l. Firefighters’ elevator control panel located in Fire Command Center Room and remote wiring.
m. Tamper resistant fasteners for signal fixture faceplates
n. Sill support angles
o. Hydraulic pump unit and controller sound isolation
p. Seismic safety valve
q. Pad hooks and vinyl-covered pads
r. Battery pack emergency car lighting. Provide separate constant pressure test button in car service compartment. Illuminate portion of normal car lighting.
s. No visible company name or logo on any equipment viewable by passengers
t. Auxiliary car operating panel for dual entry elevators
u. Wiring diagrams, operating instructions, and parts ordering information
v. System Diagnostic Equipment and instructions: The elevator installation shall be a design that can be maintainable by any licensed elevator maintenance company employing journeymen mechanics, without the need to purchase or lease additional diagnostic devices, special tools, or instructions from the original equipment manufacturer.

1) Provide onsite capability to diagnose faults to the level of individual circuit boards and individual discreet components for the solid state elevator controller.

2) If the equipment for fault diagnosis is not completely self-contained within the controllers but requires a separate, detachable device, that device shall be furnished to Sound Transit as part of this installation. Such device shall be in possession of and become property of Sound Transit.

a) Installed equipment not meeting this requirement shall be removed and replaced with conforming equipment at no cost to Sound Transit.

x. Firefighters’ Key Box: Knox-Box Elevator Key Box 1400 Series recessed mount and recessed mounting kit, or approved equal. Color: Red. Engrave instructions for use on cover in accordance with Local Fire Authority requirements. Locate box as shown on drawings. Refer to Architectural drawings for location.

y. Keys for elevator access and car operating panel in the machine room.

z. Signage engraving filled with black paint or approved etching process

27. Etched stainless steel support signs, interior cab only
   a. Material: Stainless steel, etched copy and icon. Attached to interior elevator walls with VHB and silicone.
   b. Thickness: 1/8 inch thick with eased edges
   c. Size: 3-inch x 1-1/4-inch
   d. Braille message: Stainless steel braille beads applied below 1/32-inch raised copy and Grade II braille.
   e. Color: Reverse etched stainless steel, negative space is painted black

C. Car, General
   1. Car Speed: plus or minus 10 percent of contract speed under all loading condition.
   2. Car Capacity: Safely lower, stop and hold up to 125 percent of rated load.
   3. Car Stopping Zone: plus or minus 1/4 inch under any loading condition.
   4. Door Opening Time: Seconds from start of opening to fully open:
      a. Two speed, side opening: 2.7 seconds
      b. Single speed, center opening: 1.8 seconds
   5. Door Closing Time: Seconds from start of closing to fully closed:
      a. Two speed, side opening: 4.0 seconds
      b. Single speed, center opening: 2.8 seconds
   6. Car Ride Quality
      a. Horizontal acceleration within car during all riding and door operating conditions.
      b. Not more than 20 mg peak to peak in the 1 10 Hertz range.
      c. Acceleration and Deceleration: Smooth constant and not more than 5 feet/second/second with an initial ramp between 0.5 and 0.75 second.
7. Sustained Jerk: Not more than 8 feet/second/second/second

8. Pressure: Fluid system components shall be designed and factory tested for 500 psi. Maximum operating pressure shall be 400 psi.

9. Noise and Vibration Control
   a. Airborne Noise: Measured noise level of elevator equipment and its operation shall not exceed 50 dBA in elevator lobbies.
   b. Noise level in cab shall not exceed 55 dBA for continuous noise or 60 dBA for intermittent noise under any condition including door operation and car ventilation exhaust blower on its highest speed.
      1) All dBA readings to be taken 5 feet off the floor and 1 foot from the wall using the “A”-weighted scale.
      2) Vibration Control: All elevator equipment provided under this Contract, including power unit, controller, oil supply lines, and their support shall be mechanically isolated from the building structure and electrically isolated from the building power supply and to each other to minimize the possibility of objectionable noise and vibrations being transmitted to occupied areas of the building.
   c. Limit noise level in the machine room relating to elevator equipment and its operation to no more than 80.
      1) All dBA readings to be taken 3 feet off the floor and 3 feet from the equipment using the “A”-weighted scale.

D. Car Equipment
   1. Frame: Welded or bolted, rolled or formed steel channel construction to accommodate load classification requirements.
   3. Guide Shoes: Roller type with three or more spring dampened, sound-deadening rollers per shoe. Guide shoes to be designed for the load classification requirements.
   4. Finish Floor Covering: 1/4-inch thick resin epoxy flooring with high solids with colored rubber chips in a troweled mortar system. “SoftTop” Decorative Flooring by General Polymers or approved equal, with “Shark-Grip” Slip Resistant additive to meet coefficient of friction. Color as selected by the Resident Engineer from the manufacturer’s standard.
   5. Sills: Extruded stainless steel with extruded extension between car entrance columns to face of car front return. Extruded extension to match finish of sill.
   7. Doors: Provide as specified for hoistway entrance doors.
8. Door Hangers: Two-point hanger roller with neoprene roller surface and suspension with eccentric up thrust roller adjustment.

9. Door Track: Bar or formed, cold-drawn removable steel track with smooth roller contact surface.

10. Door Header: Construct of minimum 12-gauge steel, shape to provide stiffening flanges.

11. Door Electrical Contact: Prohibit car operation unless car door is closed within tolerance allowed by Code.

12. Door Clutch: Heavy-duty clutch, linkage arms, drive blocks, and pickup rollers or cams to provide positive, smooth, quiet door operation. Design clutch so car doors can be closed while hoistway doors remain open.

13. Restricted Opening Device: Restrict opening of car doors outside the unlocking zone.

14. Door Operator: High speed, heavy-duty, master door operator capable of opening doors at no less than 2.5 feet per second. Accomplish reversal in no more than 2-1/2 inches of door movement. Open doors automatically when car arrives at a floor. Provide solid state door control with closed loop circuitry to constantly monitor and automatically adjust door operation based upon velocity, position, and motor current. Maintain consistent, quiet, and smooth door operation at all floors regardless of door weight or varying air pressure. Basis of Design: GAL MOVFR or approved equal.

15. Door Control Device
   a. Infrared Reopening Device: Black, fully enclosed device. Full screen infrared matrix or multiple beams extending vertically along edge of each leading door panel to minimum height of 7 feet above finished floor. Device shall prevent doors from closing and reverse doors at normal opening speed if beams are obstructed while doors are closing, except during nudging operation. If device fails, provide for automatic shutdown of car at floor level with doors open.
   b. Nudging Operation: After beams of door control device are obstructed for a predetermined time interval (minimum 20.0-25.0 seconds), warning signal shall sound and doors shall attempt to close with a maximum of 2.5 foot-pounds kinetic energy. Activation of the door open button shall override the nudging operation and reopen the doors.
   c. Interrupted Beam Time: When beams are interrupted during initial door opening, hold door open a minimum of 3.0 seconds. When beams are interrupted after the initial 3.0 second hold open time, reduce time doors remain open to an adjustable time of approximately 1.0-1.5 seconds after beams are reestablished.
   d. Differential Door Time: Provide separately adjustable timers to vary time that doors remain open after stopping in response to calls.
      1) Car Call: Hold open time adjustable between 3.0 and 5.0 seconds.
2) Hall Call: Hold open time adjustable between 5.0 and 8.0 seconds. Use hall call time when car responds to coincidental calls.

16. Car Operating Panel

a. One car operating panel without faceplate, consisting of a metal box containing the operating vandal resistant fixtures, mounted behind the car enclosure swing return panel(s).

   1) Panel shall be located as detailed in the Contract Drawings and as required by entrance type.

b. Suitably identify vandal resistant assemblies including floor buttons, alarm button, door open button, door close button and emergency stop switch with SCS, Visionmark or Entrada Cast Tactile symbols recessed flush mounted. Configure plates in accordance with Local Accessibility Standards, WAC 296-96-02495, including Braille. Locate operating controls no higher than 48 inches above the car floor; no lower than 35 inches for stop device and alarm button.

c. Provide minimum 3/4-inch diameter raised floor pushbuttons that illuminate to indicate call registration. Include 5/8-inch high designation of the floors served directly to the left of the pushbutton. Provide keyswitches to activate floor pushbuttons at intermediate levels. Platform and surface levels to have pushbutton only.

   1) Elevator car call buttons shall indicate floor levels consistent with Sound Transit's standard floor identification as follows:

      a) P = Platform Level
      b) M = Mezzanine Level (1, 2, 3, etc.)
      c) B = Basement Level (1, 2, 3, etc.)
      d) S = Surface Level

d. Provide alarm button at bottom of car operating panel to ring bell located on car, and sound distress signal at control panel. Illuminate button when activated.

e. Provide keyed stop switch with markings to show “run” and “stop.” Locate in locked service compartment.

f. Provide “door open” button to stop and reopen closing doors or hold doors in open position. Button operable only while car is stopped at a floor regardless of special operational features, except firefighters’ service.

g. Provide “door close” button to activate door close cycle. Cycle shall not begin until normal door dwell time for a car call has expired, except firefighters’ service.

h. Provide firefighters’ Phase II key switch with engraved instructions in accordance with Code requirements. Include light jewel, buzzer, and call cancel button.
i. Provide firefighters’ telephone jack with bezel matching adjacent controls.

j. Provide lockable service compartment with recessed flush door. Door material and finish shall match car return panel or car operating panel faceplate. Door shall contain an integral flush window for displaying the elevator-operating certificate. Inside surface of door shall accommodate mounting provisions for certificate.

k. Include the following controls with function and operating positions identified by engraved signage painted black:

1) Inspection switch
2) Light switch
3) 2-speed exhaust blower switch
4) Independent service switch
5) Constant pressure test button for battery pack emergency lighting
6) 120-volt, AC, GFCI protected electrical convenience outlet
7) Stop switch

l. Provide black paint filled, engraved or approved etched signage with size and style approved by Resident Engineer as follows:

1) Phase II firefighters’ operating instructions on main operating panel above corresponding key switch, with text in accordance with ASME A17.1.
2) Car number on main car operating panel.
3) “NO SMOKING” on main car operating panel.
4) Car capacity in pounds on service compartment door.
5) Washington State Department of Labor and Industries conveyance number in 1/2 inch tall letters.

17. Car Top Control Station: In accordance with Code. Control station shall be provided with GFCI protected outlet and work light; include on/off switch and lamp guard. An additional GFCI receptacle shall be mounted at bottom of car. Mount to provide utilization while standing in an upright position.

E. Car Enclosure

1. Provide complete car enclosure as specified herein and detailed on Contract Drawings. Provide the following features.


b. Canopy: Reinforced 14-gauge furniture steel with lockable, hinged emergency exit. Interior finish white reflective baked enamel.
c. Front and Rear Return Panels and Integral Entrance Columns: Reinforced 14-gauge non-directional finish stainless steel. Swing entire unit on substantial pivot points (minimum three) for service access to car operating panel(s). Locate pivot points to provide full swing of front return panel without interference with sidewall finish or handrail. Secure in closed position with concealed three-point latching. Provide service compartment with recessed flush cover and cutouts for operating switches.

d. Transom: Reinforced 14-gauge non-directional finish stainless steel full width of enclosure.

e. Car Door Panels: Minimum reinforced 16-gauge non-directional finish stainless steel. Same construction as hoistway door panels.

f. Base: Non-directional stainless steel with concealed ventilation cutouts. Cutouts to be protected from penetration by debris or liquids.

g. Interior Wall Finish: Non-directional finish stainless steel on aluminum honeycomb panels. As specified and as indicated. Refer to architectural drawings for details of elevator cab interiors including metal and glass panel installations.

h. Ventilation: Two speed exhaust blower mounted to car canopy on isolated rubber grommets. Morrison Products, Model AA with diffuser and grille or approved equal.

i. Lighting: Provide minimum average 15 foot-candle illumination at car floor utilizing high output LED fixtures. Provide battery standby power for operation. Provide fixtures with wiring and hookup. Coordinate with emergency lighting requirements. Provide emergency lighting integral with portion of normal car lighting system. Include required transformer.

   1) All fixtures shall be above the ceiling and not allow removal without special tools. Fixture replacement shall be able to be performed from within the elevator cab by non-elevator maintenance personnel.

j. Suspended Ceiling: Special design as shown in the Contract Drawings.

k. Handrails: 1-1/2 inch diameter stainless steel tubes.

F. Operation

   1. Simplex Automatic for single elevators, Selective Collective for elevators located in groups.

   a. Approved microprocessor-based, group dispatch, car and motion control systems as follows including, as a minimum, the features described hereafter:

      1) MCE Motion 2000
      2) Schindler Miconic HX
      3) Swift Futura Hydro
      4) Thyssenkrupp TAC 32
5) Smartrise

6) Elevator Controls Corp. Pixel

b. Operate cars as a group, capable of balancing service and providing continuity of group operation with one or more cars removed from the system.

c. Register service calls on cars from pushbuttons located at each floor and in each car. Slow down, and automatically stop cars at landings corresponding to registered calls. Make stops at successive floors for each direction of travel irrespective of order in which calls are registered except when bypassing hall calls to balance and improve overall service; stop only one car in response to particular hall call. Assign hall calls to specific cars, and continually review and modify these assignments to improve service. Simultaneous to initiation of slowdown of a car for a hall call, cancel that call. Render hall pushbutton ineffective until car doors begin to close after passenger transfer. Cancel car calls in the same manner. Give priority to coincidental car and hall calls in car assignment.

d. Operate system to meet changing traffic conditions on a service demand basis. Include provisions for handling traffic, which may be heavier in either direction, intermittent or very light. As traffic demands change, automatically and continually modify group and individual car assignment to provide the most effective means to handling traffic conditions. Assign hall calls to individual cars, continually review and update assignments; provide means to sense long wait hall calls and preferentially serve them; give priority to coincidental car and hall calls in hall call assignment and accomplish direction reversal without closing and reopening doors.

e. Use easily re-programmable system software. Design basic algorithm to optimize service based on equalizing system’s response to registered hall calls and equalizing passenger trip time to shortest possible time.

f. Required Features

1) Dispatch Protection: Backup dispatching shall function in the same manner as the primary dispatching.

2) Delayed Car Removal: Automatically remove delayed car from group operation.

3) Position Sensing: Reset car position when passing or stopping at each landing.

4) Hall Pushbutton Failure: Multiple power sources and separate fusing for pushbutton risers.

5) Duplicate communication link: All group and individual car computers.

2. Do not reverse car direction until all car calls have been answered or until all hall calls ahead of car and corresponding to direction of car travel have been answered.

3. Illuminate appropriate pushbutton to indicate call registration. Extinguish light when call is answered.

4. Other Items
a. Low-Oil Control: In the event oil level is insufficient for travel to the top floor, provide controls to return elevator to the main level and park until oil is added.

b. Independent Service: Provide controls for operation of each car from its pushbuttons only. Close doors by constant pressure on desired destination floor button or door close button. Open doors automatically upon arrival at selected floor.

c. Auto Operation: Provide field adjustable intermittent automatic operation, to be set initially for once every 3 hours through the entire run of the hoistway. Cycling shall be the full 24 hours each day throughout the year (or can be field adjusted). During such trips, elevator doors shall not open at any landing. Should a landing hall call be registered during auto operation the elevator shall stop auto operation and immediately respond to the hall call.

5. Firefighters’ Service: Provide equipment and operation in accordance with Code requirements.

6. Automatic Stopping Zone: Stop car within 1/4 inch above or below the landing sill. Avoid overtravel/undertravel, and maintain stopping accuracy regardless of load in car, direction of travel, or distance between landings.

7. Motion Control: AC type with unit valve suitable for operation specified and capable of providing smooth comfortable acceleration and deceleration. Limit the difference in speed between full load and no load to not more than plus or minus 10 percent of the Contract speed.

8. Door Operation: Automatically open door when car arrives at main floor whether car call has been registered or not.

9. Standby Lighting and Alarm: Car mounted, battery unit with solid state charger to operate alarm bell and car emergency light fixture. Battery to be rechargeable with minimum 5 year life expectancy. Coordinate location of light fixture with Resident Engineer. Provide constant pressure test button in service compartment of car operating panel. Provide lighting integral with portion of normal car lighting system. Include required transformer.

10. Battery Lowering Device: Upon loss of normal power, provide controls to automatically lower the car(s) nonstop to the lowest landing. Upon arrival at the lowest landing, the elevator doors shall open automatically and remain open until regular door time has expired. The elevator shall then become deactivated. The standby power source shall be provided via 12-volt DC battery units installed in machine room, including solid-state charger and testing means mounted in a common metal container. Battery to be rechargeable lead-acid or nickel-cadmium with a 10-year life expectancy.

11. Provide standby battery power for cab fans. Battery and fans shall provide complete cab air change per minute for a minimum of 1 hour. Upon restoration of normal power, the elevator shall automatically resume normal operation.

12. Automatic Light and Fan Shut Down: The control system shall evaluate the system activity and automatically turn off the cab lighting and ventilation fan during periods of inactivity. The settings shall be field programmable.

13. Elevator Remote Disable: During non-revenue hours, public access to and use of the elevators shall be restricted. The elevators shall be provided with control
systems to permit the Link Control Center (LCC) to shut down elevators during non-revenue hours and enable operation during non-revenue hours.

14. Sump High Water Sensor:
   a. Provide sump high water float switch with audible alarm. Switch shall be capable of notifying BMS system when capacity of sump has been exceeded.

G. Elevator Machine Equipment
   1. Arrange equipment in spaces shown on Contract Drawings.
   2. Pump Unit: Assembled unit consisting of dry or submersible positive displacement pump, induction motor, master-type control valves combining safety features, holding, direction, bypass, stopping, manual lowering functions, shut off valve, oil reservoir with protected vent opening, oil level gauge, outlet strainer, drip pan, muffler, and all mounted on isolating pads. Provide radiator type cooling unit to maintain oil at operating temperature. Enclose entire unit with removable sheet steel panels lined with sound-absorbing material. Provide closed transition SCR soft start. Design unit for 120 upstarts per hour.
   3. Pumping Unit Control Valve: The control valve shall be manifold with up, down and check valve sections. A control section including solenoid valves will direct the main valve and control up and down starting, transition from full speed to leveling speed, up and down stops, pressure relief and manual lowering. Down speed and up and down leveling shall be controlled at the main valve sections. All of these functions shall be fully adjustable for maximum smoothness and to meet Contract conditions. The manual lowering feature will permit lowering the elevator at slow speed in the event of power failure or for adjusting purposes.
   4. Tank Heater: The tank shall be provided with a temperature sensor which continuously monitors the oil temperature and transmits this information to the controller. Provide a removable thermostatically controlled (min. 500 W) screwed on heater.
   5. Oil Cooling System: The oil cooler shall be capable of removing 20,000 BTU/Hour and be provided with an adjustable thermostat. The unit shall be provided with a 10 micron filter in the oil line with a restriction sight glass with bypass in case of plugged filter. The unit shall be capable of being separated into two parts, a fan section and a pump section which can be remotely mounted from one another. The units shall be located in the elevator machine room so as not to inhibit access and maintenance of the elevator equipment.
   6. Encoder: Direct drive, solid state or magnetic tape, absolute positioning.
      a. Compartment: Securely mount all assemblies, power supplies, chassis switches, and relays, on a substantial, self supporting steel frame. Completely enclose equipment with covers. Provide means to prevent overheating.
      b. Relay Design: Magnet operated with contacts of design and material to ensure maximum conductivity, long life, and reliable operation without overheating or excessive wear. Provide wiping action and means to prevent sticking due to fusion. Contacts carrying high inductive currents shall be provided with arc deflectors or suppressors.
c. Use of SIL (Safety Integrity Level) rated devices for EPD (Electrical Protective Devices) where possible is preferred to traditional positively opened mechanical switches. These devices shall be listed/certified and labeled/marked to a SIL rating in accordance with the applicable requirements of IEC 61508-2 and IEC 61508-3 with a SIL rating equal to or greater than the SIL indicated for the applicable device shown in ASME A17.1.

d. The detection of a dangerous fault (e.g. with diagnostic tests, proof-tests, or by any other means) in SIL rated electrical/electronic/programmable electronic system (E/E/PES, or commonly referred to as "PES") that can tolerate a single fault shall cause the elevator to revert to a known fail-safe condition. Where necessary, to maintain the integrity of the SIL rated PES and maintain the fail-safe condition prior to a second fault that could lead to a dangerous condition, a manual reset shall be required to remove the SIL rated PES from the fail-safe condition.

e. Microprocessor Related Hardware

1) Provide built-in noise suppression devices that provide a high level of noise immunity on all solid-state hardware and devices.

2) Provide power supplies with noise suppression devices.

3) Isolate inputs from external devices (such as pushbuttons) with opto-isolation modules.

4) Design control circuits so that one side of power supply is grounded.

5) Safety circuits shall not be affected by accidental grounding of any part of the system.

6) System shall automatically restart when power is restored.

7) System memory shall be retained in case of power failure or disturbance.

8) Equipment shall operate properly with a 500 kHz to 1300 MHz radio frequency signal, transmitted at a power level of not less than 100 watts Effective Radiated Power (ERP) at a distance of 3 feet.

9) Equipment shall be provided with Electro Magnetic Interference (EMI) shielding within FCC guidelines.

f. Wiring: CSA labeled copper for factory wiring. Neatly route all wiring interconnections and securely attach wiring connections to studs or terminals.

g. Provide controller or machine mounted auxiliary, lockable “off” disconnect if mainline disconnect not in sight of controller and pump unit.

h. Permanently mark components (relays, fuses, and PC board,) with symbols shown on wiring diagrams.

i. Provide reduced voltage motor starting circuits with solid-state motor starter.
8. Muffler: Provide in discharge oil line near pump unit. Design shall dampen and absorb pulsation and noise in the flow of hydraulic fluid.

9. Piping and Oil: Provide piping, connections, and oil for the system. All piping to be ASTM A53, Grade B, seamless schedule 80 steel or better. All piping shall have threaded/welded fittings except that a mechanical coupling shall be provided at the discharge of the power unit and at the connection to the safety valves in the pit. Mechanical fittings shall be Victaulic Type 77, with grade T gaskets or approved equal. Buried piping shall be secondarily contained with watertight Schedule 40 PVC sleeves between elevator machine room and pit. Thermostatically controlled heat tracing and insulation shall be provided for all piping which is exposed to the outdoors, or which is indicated to be insulated on the Contract Drawings. A minimum of two sound isolation couplings shall be provided between the pump unit and oil line and the oil line and jack unit. Provide isolated pipe stands or hangers as required.

10. Connection to Remote Monitoring Interface Terminal Cabinet
   a. Provide conduit and wiring between the elevator controller and the interface terminal cabinet for remote monitoring and control of each car by the Building Management System.
      1) Refer to Electrical drawings for interface terminal cabinet locations.
      2) Receive the following dry contact inputs to effect the following control actions for each car.
         a) Phase 1 Recall – Primary (from fire alarm panel).
         b) Phase 1 Recall – Alternate (from fire alarm panel).
         c) Access control permissive.
         d) Elevator Remote Disable.
      3) Provide normally open dry contacts for each of the following status items for each car:
         a) Elevator Warning Alarm
         b) Passenger Alarm Pushbutton
         c) Phase 1 Fire Operation
         d) Phase 2 Fire Operation
         e) Elevator door closed.
         f) Independent Service
         g) Elevator at floor (one contact per floor)
   b. Provide conduit and wiring between the hoistway sump, high water sensor and the interface terminal cabinet for remote monitoring by the Building Management System.
      1) Provide normally open dry contact for each of the following status items for hoistway:
H. Hoistway Equipment

1. Guide Rails: Planed steel T-sections of suitable size and weight for the application, structural support spacing, car weight, and seismic reactions, with brackets for attachment to building structure.

2. Buffers: Spring type with blocking and supports.

3. Hydraulic Jack Assembly
   a. Cylinders: Seamless steel pipe. Two hydraulic cylinders designed to stand upright on the pit floor on either side of the car. Design head to receive unit-type packing and provide means to collect oil at cylinder head and return automatically to oil reservoir. The cylinder shall be finished with rust-inhibiting air-dry enamel. Apply two coats by brush, or spray according to manufacturer’s recommendations.
   b. Each cylinder shall have a machined steel flange at the upper end and a heavy steel bulkhead at the lower end.
   c. A packing gland with guide bearing, wiper ring and packing especially designed for the hydraulic elevator service shall be mounted at the top of each cylinder along with an oil collector ring and drain hole. The plunger seals shall be urethane cup design with integral wipers or approved equal. Replace the packing glands after all construction is completed.
   d. Provide a thermostatically controlled insulated heat tracing assembly on each cylinder to maintain the operating temperature of the oil within acceptable manufacturer’s operating range. Provide product details, ambient operating temperature guidelines and design drawings for review and approval.
   e. Plungers: Polished seamless steel tubing or pipe. The plunger surface shall be a minimum of 20 micro inches RMS and shall not exceed 35 micro-inches RMS for the entire plunger length in engagement with the cylinder seals. A stop ring electrically welded to the plunger to positively prevent the plunger from leaving the cylinder. If plunger length exceeds 24 feet, provide two or more sections not exceeding 16 feet in length, or coordinate installation of longer unit at the jobsite. Join section by internal threaded couplings. Multiple section jack units shall be factory polished while assembled and marked for proper future reassembly. Isolate plunger from car frame(s). Each piston in multi-stage jacks to have individual head bearings and packing gland assemblies.
   f. Equalization: Provide direct mechanical means of equalizing position and speed of plungers. If speed and position of cylinders are not synchronized the elevator shall self-correct by auto-lowering to lowest floor and restarting. If after two attempts to readjust the position and or speed the plungers are not synchronized the elevator shall shut down.
   g. Auxiliary Guides: Plungers shall be provided with an auxiliary guide means as per the manufacturer’s recommendations to maintain the alignment of the jack assembly.

4. Jack Support and Fluid Shut-Off Valve(s): Provide steel pit channels and support beams (if required) to support jack assembly and transmit loads to building
structure. Provide intermediate stabilizers as required. Provide manual on/off valve(s) in oil line(s) adjacent to pump unit and jack unit(s) in pit adjacent to jack unit(s). Provide a pipe rupture valve; it shall be located as close as possible to the cylinder inlet. In the event of failure in the pipe line or where the down speed exceeds allowable limits, the rupture valve shall close, bringing the car to a smooth stop.


6. Copper Electrical Wiring and Wiring Connections
   a. Conductors and Connections: Copper throughout with individual wires coded and connections on identified studs or terminal blocks. Use no splices or similar connections in wiring except at terminal blocks, control compartments, junction boxes, or conduits. Provide 10 percent spare conductors throughout. Run spare wires from car connection points to individual elevator controllers in the machine room. Provide four pairs of spare shielded communication wires in addition to those required to connect specified items. Tag spares in machine room.

      1) All wiring within hoistway shall be suitable for wet locations.

   b. Conduit: Painted or galvanized steel conduit and duct. Conduit size, 1/2 inch minimum. Flexible conduit not to exceed 36 inches in length. Flexible heavy duty service cord may be used between fixed car wiring and car door switches for door protective devices.

      1) All raceways and wiring mounted on the top of the elevator shall be suitable for wet locations. The routing of the raceways or conduit shall be routed to preclude damage from being stepped on during maintenance. If this is not possible provide steps or other additional protection.

   c. Traveling Cables: Type ET flame and moisture resistant outer cover. Prevent traveling cable from rubbing or chafing against hoistway or equipment within hoistway. Refer to “special elevator equipment” for list for spares to be included in traveling cables.

I. Entrance Equipment
   1. Door Hangers: Two-point hanger roller with neoprene roller surface and suspension with eccentric up thrust roller adjustment.
   2. Door Tracks: Bar or formed, cold drawn removable steel tracks with smooth roller contact surface.
   3. Door Interlocks: Operable without retiring cam. Paint interlocks flat black.
   4. Door Closers: Spring, spirator, or jamb/strut mounted counterweight type. Design and adjust to ensure the smooth quiet mechanical close of doors.
   5. Floor Numbers: Stencil paint 4-inch high floor designations in contrasting color on inside face of hoistway doors at each landing and adjacent to the leading edge of the door.

J. Special Elevator Equipment: The elevators shall accommodate communication subsystem equipment which shall be provided by the Contract. This equipment and its appurtenances shall be built into the elevator at the factory, unless noted otherwise.
1. CCTV Cameras: Provide and Install two cameras for each elevator
   a. Axis P3364-VE or approved equal
   b. Imaging device: 1/3 inch color CMOS 3-9 mm, vari-focal, auto iris lens
   c. Ability to control and monitor video over IP network
   d. Supported protocols: TCP/IP, UDP/IP (unicast, multicast IGMP), UPnP, DNS, DHCP, RTP, NTP
   e. Supported video resolutions: 4CIF, 2CIF, CIF, QCIF
   f. Digital compression: MJPEG, MPEG-4
   g. Web user interface with up to five simultaneous users
   h. Cameras to support low-light capability
   i. Camera shall be connected by CAT6 to an Ethernet PoE switch located in a Contractor supplied enclosure attached to the elevator cab.

2. CCTV Camera Enclosure: Provide and Install for each CCTV Camera.
   a. Install CCTV cameras with protective housings.
   b. Mini-dome with integrated camera and lens
   c. Tamper resistant hardware
   d. Rugged, high-impact, puncture-proof, opaque (smoked) dome plastic
   e. NEMA 4X and IP 66
   f. Input voltage: 18 - 30VAC, 24 VAC nominal
   g. Above ceiling dimensions: 2 inches high by 3.5 inches wide, nominal
   h. Below ceiling dimensions: 2.5 inches high by 5.5 inches wide, nominal
   i. Dome diameter: 3.75 inches, nominal
   j. Cable: RJ45-10 connector for 100Base-TX Ethernet.

3. Emergency Communication System: Complying with ASME A17.1 and the U.S. Architectural & Transportation Barriers Compliance Board’s “Americans with Disabilities (ADA), Accessibility Guidelines (ADAAG).”
   a. On activation, system dials preprogrammed number of monitoring station and identifies elevator location to monitoring station.
   b. System provides two-way voice communication without using a handset and provides visible signals that indicate when system has been activated and when monitoring station has responded.
   c. System is contained in flush-mounted cabinet, with identification, and instructions for use.

4. PA Speakers
a. Provide and install an 8 ohm public address speaker in the car canopy and connect via speaker cabling to Contractor provided PA terminals in the interface terminal cabinet in the Elevator Machine Room.

b. Provide and install Atlas UKT speakers, 95-8-7 backbox, FAMT-6 adapter plate and 60-8A round satin aluminum finish grill or approved equal.

5. Radio Antenna: Provide mounting provisions for Commprod antenna in the elevator cab ceiling. Antenna to be provided by Emergency Radio Contractor. Provide cabling from the car to the interface terminal cabinet in the machine room.

6. For elevators requiring access to non-public floors: Provide and install Lenel 2210 door controller mounted in the NEMA 4X enclosure

7. For elevators requiring access to non-public floors: Provide and install HID iClass R40 card reader in the elevator cab.

8. ST-provided PoE Ethernet Switch
   a. Install ST-provided PoE Ethernet switches.
   b. One switch shall be installed in the elevator cab and the other in the elevator machine room.
   c. Minimum of eight ports.
   d. At least one fiber port for switch to switch connection.
   e. Connect door controller and cameras to the Ethernet switch via CAT6 cable.
   f. The Ethernet switch in the elevator shall be connected to the Ethernet switch in the elevator machine room via Contractor provided fiber optic cable in the travelling cable.
   g. Power for the switch shall be provided from elevator power for the switch in the elevator and from station UPS power for the switch in the elevator machine room.
   h. Configuration settings from the Ethernet switch per Sound Transit IT department.

9. Elevator Cab Enclosure: provide a NEMA 4X enclosure, attached to the elevator cab, accessible from inside the cab, sized to install the door controller, Ethernet switch, and fiber distribution panel.
   a. Layout of devices shall provide easy maintenance access.
   b. Provide elevator power to all powered devices in the enclosure.

10. Communications Cabling and Wiring: Provide and install communications systems wiring within the traveling cable from car device to the elevator controller cabinet or the Interface Terminal Cabinet located in elevator machine room. Land wiring on terminal blocks or connectors specifically made for the intended use. Provide and install conduit between elevator controller and the Interface Terminal Cabinet.
a. All cabling to be plenum rated and shall be as follows:

b. Elevator cab PoE ethernet switch to elevator machine room ethernet switch: 6-strand plastic (multi-mode), or glass (single mode) fiber optic cable. Terminate all strands of the fiber in an FDP with LC connectors on both ends. Provide patch cords from the FDP to the switches.

c. The fiber cable provided and installed shall be rated so that it can withstand the repeated movement associated with the duty cycle of the elevator (to be noted in product data submittal) while also meeting the Sound Transit performance criteria noted below over the expected life of the traveling cables.

1) Fiber Optic Performance Criteria

a) Effective Minimum Bitrate (R) is two times the bandwidth
   \[ R \text{ [Mb/s]} = 2 \Delta f \text{ [MHz]} \]

b) Attenuation Guidelines:

<table>
<thead>
<tr>
<th>Glass Fiber</th>
<th>Wavelength (nm)</th>
<th>Attenuation Rate (db/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1550</td>
<td>0.25</td>
</tr>
<tr>
<td></td>
<td>1625</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Max Loss Budget Calculation

\[
\text{Max Loss Budget [dB]} = (\text{Length[km]} \times \text{Attenuation Rate}) + (\text{Connector pairs} \times 0.25 \text{ dB}) + (\text{Number of splices} \times 0.25 \text{ dB})
\]

<table>
<thead>
<tr>
<th>Plastic Fiber</th>
<th>Wavelength (nm)</th>
<th>Attenuation Rate (db/m)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>650</td>
<td>0.2</td>
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</tbody>
</table>

Max Loss Budget Calculation

\[
\text{Max Loss Budget [dB]} = (\text{Length[m]} \times \text{Attenuation Rate}) + (\text{Connector pairs} \times 2.5 \text{ dB}) + (\text{Number of splices} \times 2.5 \text{ dB})
\]
c. Testing Requirements

1) Minimum Effective Bitrate of 2.5 Mb/sec.

2) Losses determined from OTDR testing within the calculated Max Loss Budget.

<table>
<thead>
<tr>
<th>Fiber Material</th>
<th>Effective Minimum Bitrate</th>
<th>dB Max. Loss Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plastic</td>
<td>2.5 Mb/sec</td>
<td>25.70 dB</td>
</tr>
<tr>
<td>Glass</td>
<td>2.5 Mb/sec</td>
<td>1.73 dB</td>
</tr>
</tbody>
</table>

3) Installing contractor shall demonstrate fiber optic performance via witnessed OTDR dB attenuation testing conducted in accordance with TIA-568-C.0 Compliant Fiber Optic Test Procedures. Fiber cable must meet the above performance upon initial testing and throughout the full life of the traveling cables.

4) Installing contractor to conduct testing for bandwidth to determine effective minimum bit rate over the fully connected traveling cable between nearest elevator machine room network connection switch and cab network switch. Regardless of traveling cable length, the Effective Minimum Bitrate of 2.5Mb/sec is required.

5) Test results shall be provided to Sound Transit under Submittals.

d. Paging speaker: One copper pair 16 AWG

e. Radio Antenna: One super flex 75-ohm coaxial cable

f. Wiegand cabling from the door controller to the access card reader.

g. CAT6:

1) Elevator cab: from the cameras and door controller to the PoE Ethernet switch.

2) Elevator machine room: from the PoE Ethernet switch to RJ45 jacks on the interface terminal cabinet.

h. Instrumentation: Minimum 6 shielded twisted pairs; minimum #18 gauge instrumentation cable

i. Provide four pairs of spare shielded communication wires in addition to those required to connect specified items. Tag spares in machine room

2.04 COMPONENTS

A. Hoistway Entrances
1. Complete entrances bearing UL fire labels.

2. Frames: stainless steel at all floors. Standard bolted head to jamb connection assemblies fabricated from not less than 14-gauge material. Permanently attach rear mounted Arabic floor designation plates, centerline at 60 inches above finished floor, on both sides of jambs existing. Provide main egress landing plates with Star designation. Braille indications shall be below Arabic floor designation.

3. Track support 3/16-inch thick steel track support plate shall extend between and be bolted to the vertical steel struts with a minimum of two bolts each end.

   a. Provide leading edges of side opening doors with rubber astragals. Provide a minimum of three gibs per panel, one at leading edge, one at trailing edge and one at center of leaf with gibs in the sill groove their entire length of travel.
   b. Elevators with Rated Shaft: Provide safety glass vision panel approximately 4 inches by 20 inches in one panel of each door.
   c. Elevators without Rated Shaft: Provide 9/16 inch thick laminated tempered glass approximately 16 inches by 72 inches in each door panel

5. Sight Guards: 14-gauge, same material and finish as hoistway entrance door panels. Construct without sharp edges.


7. Sill Support Angles: Structural or formed steel designed to support doorsill, based upon car loading classification. Provide grout under the sill. Five-inch by 5-inch by 1/2-inch cold-rolled structural steel angle, extend full width of hoistway. Fasten to building structure at maximum 18 inches on center. Refer to Contract Drawings for additional details.


9. Struts and Headers: Provide for vertical support of entrances and related material.


B. Hall Control Stations

1. Pushbuttons: Provide one riser with flush-mounted faceplates. Include pushbuttons for each direction of travel, which illuminate to indicate call registration. Include approved engraved message and pictorial representation prohibiting use of elevator during fire or other emergency situation as part of faceplate. Pushbutton design shall match car operating panel pushbuttons. Provide vandal resistant pushbutton and light assemblies. Circuit boards for hall call station switches shall be conformal coated.

2. Hoistway Door Unlocking Device: Provide unlocking device with a locking escutcheon in door panel plug at all floors, with finish to match adjacent surface.

4. Faceplate Material and Finish
   c. Lobby Position Indicator: Non-directional stainless steel.
   d. Hall Pushbutton Station: Non-directional stainless steel.
   e. Hoistway Access Switch: Non-directional stainless steel.

C. Signals
1. Hall Lantern: Provide at each entrance to indicate travel direction of arriving car. Locate as detailed on Contract Drawings. Illuminate up or down lights and sound tone twice for down direction travel prior to car arrival at floor. Sound level to be adjustable from 20 80 dBA measured at 5 feet 0 inches in front of hall pushbutton and 3 feet 0 inches off floor. Illuminate light until the car doors start to close. Provide advanced hall lantern notification to comply with ADA hall call notification time. Minimum 2-1/2 inches in the smallest dimension, arrow lenses with faceplates. Provide vandal resistant lantern and light assemblies consisting of series of dots or lines for maximum visibility.

2. Car Position Indicator: Alpha-numeric digital indicator containing floor designations and direction arrows a minimum of 1/2 inch high to indicate floor served and direction of car travel. Locate fixture in each car operating panel. When a car leaves or passes a floor, illuminate indication representing position of car in hoistway. Illuminate proper direction arrow to indicate direction of travel. Provide vandal resistant indicator and light assemblies.

3. Lobby Position Indicator: Alpha-numeric digital indicator containing floor designations and direction arrows a minimum of 1/2 inch high to indicate floor served and direction of car travel. Locate fixture integral with hall lanterns at Plaza level. When a car leaves or passes a floor, illuminate indication representing position of car in hoistway. Illuminate proper direction arrow to indicate direction of travel. Provide vandal resistant indicator and light assemblies.

4. Floor Passing Tone: Provide an audible tone of no less than 20 decibels and frequency of no higher than 1500 Hz, to sound as the car passes or stops at a floor served.

5. Voice Synthesizer: Provide electronic device with easily re-programmable message and voice to announce car direction, floor, and emergency exiting instructions.

6. Card reader override: Provide conduit and wiring to control panel. Fixtures shall be located as directed by the Resident Engineer. Coordinate size and location.

7. Fire Fighters’ Control Panel: Locate in the station’s Fire Command Center Room. Furnish and install panel and all applicable wiring from each elevator to the fire panel. All supplied conductors shall conform to the requirements of NFPA 130. Associated conduit to be provided by Electrical. Fixture faceplate, No. 4 brushed finish stainless steel, including the following features:
a. Car position and direction indicator (digital readout or color SVGA display type). Identify position indicator with car number.

b. Indicator showing operating status of car.

c. Wiring to panel. Conduit from closest elevator hoistway of each group by others.

d. Two position fire fighter’s emergency return switches and indicators with engraved instructions filled with red epoxy paint.

8. Communication Failure: Provide phone line communication failure indicator light and reset keyswitch integral mounted within hall control station located at the primary phase 1 recall landing.

2.05 SEISMIC OPERATIONS AND EQUIPMENT

A. Provide design, components, and operation in accordance with ASME A17.1, Part XXIV.

PART 3 - EXECUTION

3.01 EXAMINATIONS

A. Prior to beginning installation of equipment, examine hoistway and machine room areas. Verify that no irregularities exist that affect execution of work specified. Hoistway and pit to be evaluated and confirmed as sealed and waterproofed prior to commencing installation of elevator equipment.

B. Do not proceed with installation until work in place conforms to Contract requirements.

3.02 INSTALLATION

A. Install all equipment in accordance with manufacturer’s instructions, referenced Codes, these Specifications and approved submittal.

B. Install machine room equipment with clearances in accordance with referenced Codes and these Specifications.

C. Install all equipment so it may be easily removed for maintenance and repair.

D. Install all equipment for ease of maintenance.

E. Install all equipment to afford maximum accessibility, safety, and continuity of operation.

F. Replace or refurbish all material to meet performance requirements outlined in this Section prior to station operation. There will be an extended period of time from the point that the elevators are installed to the final acceptance and station normal operation.

G. Remove oil, grease, scale, and other foreign matter from the following equipment and apply one coat of field-applied machinery enamel.

1. All exposed equipment and metal work installed as part of this work that does not have architectural finish.

3. Neatly touch up damaged factory-painted surfaces with original paint and color. Protect machine-finish surfaces against corrosion.

3.03 FIELD QUALITY CONTROL
A. Work at jobsite will be checked during course of installation. Full cooperation with reviewing personnel is mandatory. Accomplish corrective work required prior to performing further installation.
B. Have Code Authority acceptance inspection performed and complete corrective work.

3.04 ADJUSTMENTS
A. Install rails plumb and align vertically with tolerance of 1/16 inch in 100 feet 0 inch. Secure joints without gaps and file all irregularities to a smooth surface.
B. Static balance car to equalize pressure of guide shoes on guide rails.
C. Lubricate all equipment in accordance with manufacturer’s instructions.
D. Adjust motors, valves, controllers, leveling switches, limit switches, stopping switches, door operators, interlocks, and safety devices to achieve required performance levels.

3.05 CLEANING
A. Keep work areas orderly and free from debris during progress of Contract. Remove packaging materials on a daily basis.
B. Remove all loose materials and filings resulting from work.
C. Clean machine room equipment and floor.
D. Clean hoistways, car, car enclosure, entrances, and operating and signal fixtures per submitted procedure as required to meet sign off requirements of L&I.

3.06 DEMONSTRATION
A. General: Furnish labor, materials, and equipment necessary for tests. Notify Resident Engineer 5 days in advance when ready for final review of unit or group. Final acceptance of installation will be made only after all field quality control reviews have been completed, identified deficiencies have been corrected, all Sound Transit's information and certificates have been received, and the following items have been completed to satisfaction of Resident Engineer.

1. Workmanship and equipment comply with these Specifications.
2. Contract speed, capacity, floor to floor, and door performance comply with these Specifications.
3. Performance of following are satisfactory:
   a. Starting, accelerating, running
   b. Decelerating, stopping accuracy
   c. Door operation and closing force
   d. Equipment noise levels
   e. Lighting levels
f. Signal fixture utility

g. Overall ride quality

h. Performance of door control devices

i. Operations of special security operation and floor lock-off provisions.

j. Demonstrate CCTV Camera image on computer connected to data cable to Interface Terminal Cabinet

k. Demonstrate that PA system works by connecting to an amp and broadcasting voice over speaker.

l. Demonstrate phone installation by dialing designated ST control center.

m. Demonstrate each monitoring and control signal to Building Management System at Interface Terminal Cabinet

4. Test Results

a. In all test conditions, obtain specified speed, performance times, stopping accuracy without re-leveling, and ride quality to satisfaction of the Resident Engineer.

b. Temperature rise in motor windings limited to 120 degrees F above ambient. A full-capacity, 1-hour running test, stopping at each floor for 10 seconds in up and down directions, may be required.

B. Performance Guarantee: Should tests reveal defects, poor workmanship, variance or noncompliance with requirements of specified Codes and/or ordinances, or variance or noncompliance with the requirements of these Specifications, complete corrective work to satisfaction of Resident Engineer at no cost:

1. Replace equipment that does not meet Code or these Specifications requirements.

2. Perform work and furnish labor, materials, and equipment necessary to meet specified operation and performance.

3. Perform and assume cost for retesting required by Governing Code, Authority, and Sound Transit to verify specified operation and/or performance.

C. Field Review Scheduling: Schedule progress and final equipment reviews with Resident Engineer. Reply promptly, in writing, to corrective work indicated on Resident Engineer’s progress and/or final review reports, indicating status, schedule for completion, and questions.

3.07 TRAINING

A. Provide orientation and training to familiarize Sound Transit operations personnel with the features and operation of the elevator.

1. Include step-by-step instructions for elevator operations, controls and features, including procedures for locking down elevators when not in service.

2. Training shall include complete familiarization of the elevator and elevator machine room, including components installed within the machine room.

3.08 COMMISSIONING
A. Refer to specifications Section 14 08 00 Commissioning of Conveying Equipment for further requirements pertaining to the work in this Section.

END OF SECTION
SECTION 14 31 00
ESCALATORS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing heavy duty escalators as specified and as detailed on the Contract Drawings, including maintenance as described herein.

B. Related Work Specified Elsewhere:

1. Wellway and Pit:
   a. Clear, plumb, wellway with variations not to exceed 1 inch at any point.
   b. Floor pockets and/or structural beams for support of escalator truss at each end and at intermediate locations as shown on the Contract Drawings. Support beam deflection shall not exceed 1/1666 of span under static load.
   c. Fire resistive enclosure of escalator truss including ends, sides, and bottom in ceiling plenum.
   d. Patching and finishing around escalator landing plates after installation.
   e. Cladding and finishing of exposed truss surfaces.
   f. Waterproof pit. All escalator pits shall be provided with indirect drains to prevent accumulation of water.
   g. Protect open wellways during construction in accordance with OSHA regulations.
   h. Protect escalator truss, steps, landing plates, balustrades, handrails, and special metal finishes from damage.
   i. Venting or other means to prevent accumulation of smoke and gas in escalator truss as required by Local Building Code.
   j. Fire sprinklers in accordance with local Code requirements with protective guards.

2. Electrical Service, Conductors, and Devices:
   a. Light with guard and Ground Fault Circuit Interrupter (GFCI) convenience outlet in each pit and machine room space. Provide wet label fixtures.
   b. Three-phase mainline copper power feeder to terminals of each escalator controller in the remotely located control cabinet or room with protected, lockable OFF, disconnect switch.
c. Three-phase copper power feeder with protected, lockable OFF disconnect located in machine room or cabinet for combined combplate and truss heater circuit.

d. The contractor shall arrange and pay for three-phase temporary power with the same characteristics as the permanent power to be made available to the installer at the time of the setting of the truss. Permanent power shall be made available for testing.

e. Single phase copper power feeder to each remote escalator control cabinet heaters with individual protected, lockable OFF, disconnect switch located in machine room space.

f. Single phase copper power feeder to each lower end and upper end escalator pit for balustrade and combplate lighting with individual protected, lockable OFF, disconnect switch located in machine room space.

C. Structural Requirements

1. The installer shall provide escalator truss mounting angles and intermediate truss supports with attachments, sized as required to install escalators into wellway structural support system shown on the contract drawing.

2. Escalator intermediate support points shall be provided by the installer where indicated on drawings. Details and calculations shall be submitted by the escalator installer for approval by the owner.

3. Reaction loads shall be indicated on contract drawings.

4. Seismic designs shall be based on actual story drift data from the building’s structural engineer.

5. Seismic calculations shall be based on the design loadings in this document.

6. Brake load:
   a. Static brake load (load per step on the total number of exposed steps on the incline) shall be per code minimum.
   b. Dynamic brake load (load per step running in the down direction on exposed steps on the incline) shall be per code minimum.

7. Step Load:
   a. Step, step chain and motor duty load shall be per code minimum step loading.

D. Environmental Requirements

1. Escalators shall be capable of operating with fully specified performance capability while exposed to the following climatic and environmental conditions:
   a. Exterior installations: All escalators shall be treated as being outdoors and designed to meet the requirements of exterior installations. Escalators shall be designed to operate while exposed to the natural elements of weather, including sunlight, rain, slush, snow and ice; all conditions of relative humidity while exposed to salt, deicing chemicals,
airborne dust, and debris, and corrosive elements; and a dry-bulb temperature range of -10 to 105 °F.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Society of Mechanical Engineers (ASME):
   a. ASME A17.1 Safety Code for Elevators and Escalators
   b. ASME A17.2.3 Guide for Inspection of Elevators, Escalators and Moving Walks
   c. ASME A17.5 Elevator and Escalator Electrical Equipment

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   c. ASTM A568 Standard Specification for Steel, Sheet, Carbon, and High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, General Requirements
   d. ASTM A1008 Standard Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability
   e. ASTM A1011 Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy with Improved Formability
   f. ASTM B209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
   g. ASTM B221 Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles and Tubes

   a. NFPA 70 National Electrical Code
   c. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

4. National Electrical Manufacturers Association (NEMA)

5. Seattle Building Code (SBC)

   a. ANSI/AWS D1.1 Structural Welding Code-Steel
b. ANSI/AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination

7. Occupational Safety & Health Administration (OSHA)
   a. 29 CFR Part 1926, Safety and Health Regulations for Construction

8. Americans with Disabilities Act of 1990 (ADA)
   a. 28 CFR Part 36. ADA Standards for Accessible Design


1.03 DEFINITIONS

A. Terms used are defined in the latest edition of ASME A17.1, Safety Code for Elevators and Escalators.

B. Reference to a single device or part of the equipment applies to the full number of devices or parts required to complete the installation as specified.

C. Machine room refers to the upper pit of each respective escalator.

1.04 SUBMITTALS

A. Pre-revenue Warranty Maintenance Plan.
   1. Submit a detailed Pre-revenue Warranty Maintenance Plan.

B. Scaled and Fully Dimensioned Layout: Plan of pit, wellway, indicating equipment arrangement and elevation section of wellway.
   1. Product information shall be submitted with an index listing each product, along with the application method of the product, approximate quantity of product per escalator, and the component the product is applied to or associated with. Include all elements manufactured by others to be included in the escalator.
   2. Location of lower and upper working points, proposed attachment for escalator truss to entrance structure, intermediate support details, thermal expansion joint, load reactions, rated capacity and speed, handrail details, and machine room space and access.
   3. Location of major mechanical and electrical components within truss, electric interface connections, and drainage connections.
   4. Electrical layouts showing location of truss lighting, light switches, light fixtures, maintenance receptacles, and safety devices.
   5. Schematic and electrical wiring diagrams of power distribution and control systems, including wiring of safety devices and interface connections for remote surveillance for each typical escalator, or group of escalators.
   6. Location of operating panel in upper and lower-end balustrades. Show following items:
      a. Stop button
b. Start and direction selection switch

7. Show location of following items:
   
a. Outline of escalator truss in profile and plan
b. Elevation of escalator balustrade
c. Vertical section through balustrade
d. Truss midway between working points
e. Reaction loads and location
f. Truss stanchion
g. Track system and supports
h. Drive system
i. Step nosing radius at upper and lower ends
j. Drive chains and gear train
k. Step chain or step links (including chain pitch, step and trailer wheels)
l. Step assembly (including axle, step tread, frame and riser)
m. Handrail system (including profile, guides, drive and tension device)
n. Support details with vibration isolation (including upper, lower, intermediate and slip joint), balustrade deck cover, interior panels, skirt panels and their moldings
o. Safety switches and operating devices
p. Motor and emergency brakes
q. Floor plates
r. Speed governor
s. Metal gauges and identification of finishes
t. Radial, vertical and horizontal dimensions required for manufacture, and positions of lower and upper working points
u. Attachment of truss to structure
v. Major mechanical and electrical components within truss
w. Drainage and electrical interfaces
x. Hand and finger guards
y. Ceiling intersection guards
z. Vibration isolation
aa. Passenger instruction signs;
bb. Emergency stop button; and operating panel in upper and lower balustrades (including stop button, start and direction selection switches, and fault finder receptacle).

c. All bearing ratings, identification and catalog numbers shall be provided.

d. A complete schematic diagram shall be provided for the controller and all electrical devices.

ee. Certificate holder; including but not limited to, test certificates for step chain shall be provided for approval.

8. Engraved conveyance number


11. Balustrade Section: Vertical section taken completely through balustrade and truss midway between working points.

12. Escalator cladding: Vertical section taken completely through escalator cladding, handrail, and decking at mid-flight at upper and lower deck where handrail and decking are level or parallel to floor.

13. Relationship to adjacent work including modifications of details, dimensions, and configuration for elements to accommodate selected products for Work of this Section.

14. Use AWS symbols for defining type, size, and length of welds. Indicate which welds are to be performed in shop and which welds are to be performed in field.

C. Product Data

1. Transmit Material Safety Data Sheets (MSDS).

D. Finish Material: Submit samples of actual finished material for review of color, pattern and texture by Resident Engineer. Compliance with other requirements is the exclusive responsibility of the Contractor.

1. Type 316 stainless steel

2. Lighting fixtures

3. Skirt brush device including attachment means

E. Transmit: Test Procedures.

F. Transmit: Certificates and Test Reports - Written certified reports for required tests, recording dates performed, test method, test results, interpretation of results, and recommended action. Include Certificate and Test Reports for following:

1. Manufacturer’s certificate of rated load test;

2. Manufacturer’s certificate for the chain breaking load

3. Contractor’s standard field test and data report;
4. Certificate of inspection by the Washington State Department of Labor and Industries

5. Operating permit issued by the Washington State Department of Labor and Industries

G. Transmit: Welder certifications and qualified welding procedures and necessary documentation, as required in, Metal Fabrications for review and acceptance.

H. Operations and Maintenance Manuals

1. In addition to requirements stated elsewhere in the Contract Documents, the Operations and Maintenance Manual shall include the following:

   a. Neatly bound sets of written information necessary for proper operation, maintenance and adjustment of equipment. Generic information that does not pertain to the equipment installed shall not be included in the manual. Include the following as minimums:

      1) Complete instructions regarding operation and maintenance of the specific equipment and components installed, including disassembly and assembly of drive system, handrail drive assembly and track system.

         a) Include a complete functional description of each component of the escalator and complete procedures and step-by-step guide for maintenance, repair and overhaul. Instructions shall be at the adjuster’s level and include all necessary measurements, including clearance, gap and torque readings.

         b) Include complete, illustrated, exploded views of all assemblies and a complete, illustrated, exploded view for identifying all system parts.

         c) Include operating instructions specific to each escalator, including location, function and operation of all controls, gauges, indicators and switches, as well as emergency procedures.

      2) Complete nomenclature of replaceable parts, part numbers, current cost and warehouse location. If the product source is another vendor, then the installer shall include the name and address of the other vendor.

      3) Sample copies of a preventive maintenance chart specific to the installed equipment and components.

      4) Descriptions of safety devices.

      5) Safety rules, tests and procedures, including testing of all systems and subsystems.

      6) Procedures and settings for adjusting safety switches, brake, handrail tension, handrail chain drive tension, step chain tension, track system, and mechanical components, including pictorials. Include all recommended measurement values such as torque and pressure.
7) Instructions for removing the floor plate, replacing comb segments, and removing and installing steps and interior panels.

8) Troubleshooting techniques.
   a) Include a full and complete list of fault and error codes for each escalator.

9) Detailed lubrication and cleaning schedule indicating weekly, monthly, quarterly, semiannual and annual lubrication; and a description of each lubrication point, lubrication type and specification. In addition, a laminated lubrication chart shall be mounted on the controller cabinet and shall include lubrication instructions including recommended grade of lubricants.

10) List of special tools required for escalator inspection, adjustment, maintenance and repairs.

11) List of recommended spare parts and stock quantities for routine maintenance of the equipment. Include a list of spare parts considered critical and for which long lead time frames for acquisition would result in extended equipment down-time.

12) Control and schematic electrical wiring diagrams of the controller, including wiring of safety devices to connections with remote indication and control panels for each escalator and group of escalators.

13) Electrical layout showing placement of lighting, light switches, receptacles, light fixtures, disconnect switches and convenience outlets in the truss envelope and pits.

14) Complete detailed drawings and wiring diagram of escalator fault finding device and connection to annunciator panel.

15) Interface drawing that indicates all related devices.

16) As-Built drawings shall be provided with the Operations and Maintenance Manuals. As-built drawings shall include the same items as indicated in Construction Submittals/Shop Drawings with all items updated to final as-built condition.

17) Straight-line wiring diagram of as-installed escalator circuits, with index of location and function of components, shall be provided with the Operation and Maintenance Manuals. In addition, mount installation wiring diagrams on panels, racked, or similarly protected, in escalator machine room space. Provide one complete reproducible master set rolled and in a protective drawing tube. Maintain with additions of all subsequent changes during the Warranty and Extended Maintenance periods. These diagrams are Sound Transit’s property.

18) Detailed Warranty Maintenance and Revenue Service Maintenance programs, showing functions to be performed and their scheduled frequency.

I. 4 sets of neatly tagged keys for all switches and control features.

1. All escalators within the same facility shall be keyed identically.
J. Provide electronic file of all escalator programs and a printed program list.

K. Special Tools
   1. Provide, for each escalator installed, a complete set of all special tools required for escalator maintenance.
   2. Diagnostic equipment: Provide diagnostic test device complete with instructions, access codes, adjuster’s manuals, and set-up manuals for adjustment, diagnosis and troubleshooting, and performance of routine safety tests.

1.05 QUALITY ASSURANCE

A. Compliance with Regulatory Agency: Comply with most-stringent applicable provisions of the Code and/or Authority outlined in Section 1.02, including revisions and changes in effect on date of these Contract Specifications.

B. Welding shall be performed in accordance with the requirements of the AWS. Welders shall produce evidence of current certification by the AWS.

C. Factory Visit
   1. ST may elect to visit the factory where the escalator is being manufactured.
   2. The escalator shall be tested in the factory with the controller to be shipped with the escalator. If ST chooses to visit the factory, they shall observe the steps and chain in operation and test selected devices.

1.06 DELIVERY, STORAGE, AND HANDLING

A. When escalator manufacturing process is complete and facility access is complete, deliver escalators and equipment to Work site in manufacturer’s unopened protective packaging.

B. Transport, handle, and store materials in manner to ensure preservation of material quality and fitness for incorporation in Work. Store material in a manner to facilitate inspection and prevent damage.

C. Erection equipment is subject to review and acceptance by the Resident Engineer upon delivery to Work site. If equipment is deemed by the Resident Engineer to be unacceptable or hazardous to personnel and property, promptly bring to acceptable condition, or remove from Work site. Obtain approval from the Resident Engineer for use of heavy moving and erection equipment supported by station structures prior to use.

D. Protect equipment and exposed finishes during transportation, erection, and construction.

1.07 MAINTENANCE

A. Pre-revenue Warranty Maintenance:
   1. Provide full service Maintenance. This period shall commence upon installation and extend to the start of Revenue Service.
      a. Full service maintenance shall include standard monthly maintenance, replacement parts, below and annual testing.
   2. Provide preventive maintenance and callback service during normal working hours. Systematically examine, adjust, clean, and lubricate equipment. Repair or replace defective parts using parts produced by the manufacturer of installed
equipment. Maintain escalator control space at upper landing, wellway and pit in clean condition. Defective is defined to include, but not to be limited to; operation or control system failures, performance below required minimum, excessive wear, unusual deterioration or aging of materials or finishes, unsafe conditions, the need for excessive maintenance, abnormal noise or vibration, and similar unsatisfactory conditions.

3. Exercise each escalator during monthly maintenance visits. Exercising of equipment shall consist of continuous operation for one hour. Direction of travel shall be reversed each month.

4. All warranty and maintenance work shall be performed by a company that has a current code compliant Maintenance Control Program (MCP) on file with L & I. Warranty maintenance shall meet the MCP criteria as outlined in ASME A17.1 as well as all manufacturer’s recommended maintenance.

5. Equipment Manufacturer is responsible for upgrades and revisions of software and documentation of associated revision to the Operations and Maintenance Manual.

6. The Contractor shall document all maintenance and transmit maintenance records to Sound Transit.

B. Extended Warranty Maintenance:

1. Provide Extended Warranty Maintenance for a five year period commencing at the start of Revenue Services per Appendix A “Extended Maintenance Services Scope of Work” and as generally described below.
   a. Submit detailed Extended Maintenance and Revenue Service program, showing functions to be performed and their scheduled frequency.

2. Provide full service preventive maintenance as recommended by the manufacturer and in accordance with all applicable codes, and 24-hour emergency callback service. Systematically examine, adjust, clean, and lubricate equipment. Repair or replace defective parts using parts produced by the manufacturer of installed equipment. Maintain escalator control space, wellway and pit in clean condition.

3. Removal of units from beneficial usage for maintenance purposes shall be coordinated with and approved by Sound Transit, unless removal is necessitated for emergency repair or adjustment. Normal preventive maintenance service shall be performed during off-peak operating hours.

4. All units shall be available for use an average of 98.7% of property hours of operation over each three-month period during Warranty Maintenance service. This includes allowance for equipment out of service time as the result of callbacks, scheduled preventive maintenance, and repairs. Contractor’s failure to meet this unit availability provision for two consecutive three-month periods for any single elevator or escalator, or group of units, shall trigger an automatic maintenance audit by Sound Transit. Contractor agrees to expeditiously take corrective action in regard to identified deficiencies. Further, Contractor acknowledges Sound Transit’s right to pass cost of said audit to Contractor.

5. All warranty and maintenance work shall be performed by a company that has a current code compliant Maintenance Control Program (MCP) on file with L & I.
6. Equipment Manufacturer is responsible for upgrades and revisions of software and documentation of associated revision to the Operations and Maintenance Manual.

1.08 PERMIT, TEST AND INSPECTION

A. Obtain and pay for permit, license, and inspection fee necessary to complete the installation. Installation will be considered complete when the governing authority of Washington State Department of Labor and Industries has issued a permanent operating permit for each escalator.

B. Perform tests required by the Elevator Section of the Washington State Department of Labor and Industries. Perform tests in accordance with procedures described in ASME A17.2 Inspector’s manual for Electric Elevators and Escalators and as required by the authorities having jurisdiction in the presence of the Resident Engineer.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Approved Manufacturers:
   1. KONE
   2. Schindler
   3. Thyssenkrupp
   4. Or approved equal

2.02 MATERIALS

A. General:
   1. All escalators shall consist of a corrosion resistant truss assembly (galvanized), step-drive units, steps and step chains, driving machine and controller, safety devices, comb and deck plates, handrails and deck trim, newels and balustrades, balustrade lights, and other accessories and appurtenances. The sides and underside of the truss, exterior of the escalator, and machinery spaces shall be enclosed.
   2. No wood or wood products shall be used in escalators.

B. Steel:

C. Stainless Steel: Type 316 complying with ASTM A167, with standard tempers and hardness required for fabrication, strength and durability. Apply mechanical finish on fabricated work in the locations shown or specified, (Federal Standard and NAAMM nomenclature), with texture and reflectivity required to match Resident Engineer’s sample. Protect with adhesive-paper covering.


3. Non-directional orbital uniform finish: 80 grit orbital sanding over standard mill plate or shape to produce a uniform non-directional satin finish with 90 percent of mill marks removed to match Resident Engineers visual sample.

D. Aluminum: Extrusions conforming to ASTM B221; sheet and plate conforming to ASTM B209.

1. Casings and extrusions: Commercial mill finish.

E. Galvanizing:


2. Other galvanizing: ASTM A123, ASTM A153, ASTM A385 or ASTM A386, as applicable.

3. Galvanizing touch-up: Zinc dust coating, MIL-P-21035 or MIL-P-26915.

F. Fasteners:

1. Fasteners shall be compatible with materials being fastened. Fasteners shall be furnished with self-locking nuts or retaining rings (spring washers, toothed disks).

2. Fasteners shall be equal to or of greater corrosion resistance than the most corrosion resistant metals being fastened.

G. Corrosion Protection:

1. After welding, the truss shall be hot dipped galvanized with a coating in accordance with ASTM A90. A 100-percent zinc thermal spray coating to ASNI/AWS C. 18-93 is an acceptable alternative.

2. Cast metal parts such as gear housings, chain sprockets and return station half circles shall be painted with a rust inhibitor primer coat after preparation by sandblasting.

3. Steel parts that are not specified to be galvanized shall be painted to meet High Performance Coating requirements. Bright or uncoated axles, shafts, etc. shall be protected by zinc chromate or chrome plating.

H. Paint: Clean exposed metal of oil, grease, scale, and other foreign matter and factory paint one shop coat of manufacturer’s standard rust-resistant primer. After erection, provide one finish coat of industrial enamel paint. Galvanized metal need not be painted.

I. Prime Finish: Clean all surfaces receiving a baked enamel finish of oil, grease, scale, and other foreign matter. Apply one coat of rust-resistant mineral paint followed by a filler coat over uneven surfaces. Sand smooth and apply final coat of mineral paint.

J. Baked Enamel: Prime in accordance with Article 2.02E above. Apply and bake three additional coats of enamel in the selected solid color.

K. All equipment and metalwork installed as a part of this Work, which does not have special architectural finish and which is exposed in the wellway, shall be thoroughly cleaned of oil, grease, scale, and other foreign matter and given one coat of field-applied machinery
enamel. Damaged factory-painted surfaces shall be neatly touched up with original paint and color.

L. All natural metals shall be stretcher-leveled, re-squared sheets. All surfaces shall be smooth and without waves.

2.03 EQUIPMENT

A. General Operation

1. Escalators shall be heavy duty escalators suitable for public transit. The escalator design shall incorporate finishes, materials and components to deter and resist vandalism.

2. All escalators supplied within this contract shall be the products of a single manufacturer.

3. Escalators shall be designed for the following conditions:
   a. Hours of operation shall be considered as 20 hours per day, 7 days per week.
   b. Direction of travel shall be considered as either direction, and unit shall be up-and-down reversible. Unit shall be capable of reversing the direction of traveling without significant adjustments or maintenance activity.
   c. Escalator components shall be designed based on the design loads as defined herein, following applied duty cycle during operation:
      1) Three hours with 100 percent design load
      2) Six hours with 50 percent design load
      3) Eleven hours with 25 percent design load

B. Escalator Features

1. Number: As specified and detailed on the Contract Drawings

2. Size: 48 inches wide (40 inch step)

3. Speed: 100 feet per minute (fpm)

4. Maintenance Speed: <= 25 fpm

5. Rise: As noted on Contract Drawings.

6. Floors Served: As specified and detailed on the Contract Drawings

7. Angle of Inclination: 30 Degrees

8. Operation:
   a. Escalators in Pairs: Reversible under full load as defined by ASME A17.1
   b. Single Escalators: Non-reversible, up only operation

9. Drive Motor Gear Box: worm helical
10. Balustrade Finish: Non-directional stainless steel
11. Deck Configuration: High
12. Deck Finish: Non-directional stainless steel
13. Molding and Trim: Match deck finish
14. Skirt Panels: Satin finish Stainless steel with anti-friction coating applied
15. Handrail Color: Black with white inserts
16. Step Tread and Riser: Cleated and meshed with adjacent step with tread demarcation inserts, tread sides and nosing
17. Upper Track Radius: 8 feet 6 inch radius
18. Lower track radius: 6 feet, 6.75 inch radius
19. Demarcation Color: Yellow
20. Power Supply: 480 Volts, 3 phase, 60 hertz
21. Additional Features:
   a. Step demarcation lighting
   b. Emergency stop buttons
   c. Caution signs at each landing
   d. Floor intersection guards
   e. Truss extensions
   f. Floor Landing Plates and Landing Plate Extensions as required at adjacent escalators.
   g. Truss and Combplate heaters (480V)
   h. Combplate lighting
   i. Skirt/balustrade Lighting
   j. Fault finder mounted in inner deck or at stop switch location
   k. Intermediate supports located as detailed
   l. Balustrade mounted passenger detection sensor for sleep mode. Bollard mounted beam type detection sensors are not acceptable.
   m. Oil Water Separator.
   n. Power supply provided as detailed in the Contract Drawings. Provide a junction box and conduit as needed based on a power supply located at the lower end of the escalator.
   o. Anti-slide devices on decks when the outer edge of the deck is 8 inches or greater from the edge of the handrail, or on adjacent escalators when the unobstructed distance between the edge of facing handrails is
12 inches or greater. Anti-slide devices to be a minimum 2 inches diameter by 1 inch height stainless steel with concealed mounting.

p. Stainless steel frame with polycarbonate glazing for mounting escalator operating permit. One per escalator.

q. High water level sensor/switch.

22. Performance

a. Step Speed: Unit shall be capable of operating at Contract speed under all loading conditions in either direction of travel.

   1) Rated speed shall not exceed 100 fpm. The no-load-to-full-load speed shall not exceed 4 percent of the rated speed.

b. Handrail Speed: Consistent with step speed.

c. Provide sleep mode functionality.

   1) Provide variable frequency drives (VFD) for reversible escalators in pairs.

   2) Provide variable frequency drives for single up-only escalators.

23. Operation

a. Each unit shall be capable of operating smoothly and quietly at rated speed with synchronized step and handrail operation and speed in either direction of travel.

b. Each unit shall be provided with all controls, programming and equipment necessary to meet the following sleep sequence of operations:

   1) Detection sensors at each landing shall continually monitor for passengers boarding and leaving the escalator.

      a) Detection of approaching passengers shall occur sufficiently in advance of boarding to allow the escalator to reach full operating speed prior to a passenger walking at normal speed (270 ft/min) reaches the combplate.

   2) If no passenger is detected for greater than 3 times the amount of time necessary to transfer a passenger between landings (adjustable), the escalator shall enter a sleep mode.

      a) Sleep: Variable Frequency Drive (VFD) ramps escalator speed down to a minimum speed not less than 10 ft/min

         i) The deceleration rate shall not exceed 1.0 ft/sec/sec.

   3) Upon detection of a boarding passenger the VFD ramps the escalator speed up 100 ft/min.

      a) The acceleration rate shall not exceed 1.0 ft/sec/sec.
b) The rated speed shall not be exceeded.

4) If a passenger is detected approaching against the direction of escalator travel at the egress landing, the VFD shall ramp the escalator up to rated speed and sound the alarm at the approaching landing before the passenger reaches the combplate.

5) Upon failure of the passenger detection sensor the escalator shall default to continuous operation at rated speed.

24. Seismic Features
   a. Provide slip joints pinned and as designed by a Structural Engineer registered in the State of Washington. Provide sliding assembly based on actual story drift and approved by Sound Transit.
      1) The slip joint slide bearings shall not use grease for lubrication.
   b. Provide seismic switch to disable escalator if a seismic event occurs. Locate beneath soffit at lower end, or other approved remote location, outside of truss.

25. High Water Sensor
   a. Water level sensors shall be provided in the bottom pit within the truss envelope of each escalator and incorporated into the safety circuit. High water shall stop the escalator and prevent it from being started. When the water level goes down the escalator shall automatically start without reset

26. Remote Stop Features
   a. Provide capability for future implementation of remote stop audible alarm, delay and controlled deceleration as prescribed in NFPA 130 Sections 5.5.2.1.

C. Machine Room Equipment
   1. General: The controller shall be located remotely as indicated in the contract drawings. The limit of wire length between the upper pit of the escalator and the escalator controller is 325 ft.
   2. Driving Machine: Worm geared or helical spur gear reduction unit coupled directly to drive motor.
      a. V-belt and tooth belt drives shall not be acceptable.
      b. Head shaft bearings shall be rated for ABMA L10 200,000 hours.
      3. Gear Box Requirements
         a. Gear bearings shall be rated with an ABMA L10 life of 200,000 hours and housed in an oil-tight, dust-proof case. The case shall provide a convenient method of draining the oil.
         b. Synthetic lubricants shall be used.
c. Rotating parts shall be provided with a means for lubrication and retention of lubricants.

d. Sealed bearings shall be used.

e. Exposed, moving drive elements shall be protected by metal housings, which shall provide access for lubrication of components.

f. A low oil sensor shall be provided to prohibit starting of the escalator on automatic operation with low oil in the gear case.

4. Fault Finder: Provide fault-locating instrumentation to monitor supply voltage, drive unit, wheels, drive chains, step chains, safety circuits, emergency brake lubrication oil, up thrust switch, handrail entry, broken handrail, skirt switch, top and bottom step chain, or step-link switch, combplate, under/over speed switch, low lubricant level indication, and emergency stop switch. Permanently install fault-finding equipment at each escalator. Provide display to indicate trouble code in outer deck at readily visible location. Design to resist vandalism.

a. Drive Motor: Three-phase, operating at no greater than 1200 revolutions per minute (rpm). The motors shall be totally enclosed with external cooling fins.

b. Design motors to operate in confined, unvented spaces. Motor insulation Class F or greater.

1) Provide heater as required to meet manufacturer’s temperature requirements.

c. Motor starting: incorporate reduced current starting.

5. Brake Requirements

a. Operation: Safely decelerate, stop, and hold rated load in accordance with Code requirements.

1) For escalators operating in the down direction, application of the brakes shall not cause the escalator to stop at a rate greater than 3 feet/second/second.

b. Motor brake:

1) The brake coil shall be insulated to Class F.

2) A monitor shall be provided, and if brake lining becomes insufficient for safe usage, restart of the escalator shall be prevented.

c. Step Band Lock

1) A step band lock shall be manually applied and mechanically engaged to prevent movement of linkages while the escalator is disconnected from its power supply.

2) An electrical interlock that shall prevent escalator drive motors from starting while the step band lock is engaged shall be provided.
6. Controller: Provide manufacturer's standard non-proprietary controller. Controller shall be capable of all features and modes of operation as specified herein. Wire to identify terminal block studs. Identifying symbols or letters identical to those on wiring diagrams permanently marked adjacent to each component on the controller. Enclose all components in a lockable steel cabinet located in a non-public space outside of the escalator pits. Provide mainline circuit breaker and means to protect against overload and single phasing. Provide Washington State Department of Labor & Industries conveyance number and escalator number on controller cover.

a. The escalator controller shall have one dedicated serial port, which supports RS-232-C signals. It shall be accessible in ladder logic and provide support for point-to-point and slave SCADA communication protocol systems. Alternatively, it must be usable for programming purposes or for access to remote programmers via the Building Management System interface.

b. The escalator control equipment shall contain diagnostic capabilities as required for the ease of complete maintenance. The diagnostic system shall be an integral part of the controller, capable of storing the last 99 safety device faults and provide user-friendly interaction between the service person and the controls. All such systems shall be free from decaying circuits that must be periodically reprogrammed by the manufacturer.

1) A permanently mounted full-color view panel capable of providing fault and operating data shall be mounted external to the pit and protected from moisture.

2) Troubleshooting capabilities shall include the ability to easily identify a single activated switch in a circuit that may include multiple switches.

c. Switchgear and controller shall be mounted in NEMA 4X cabinets with strip heaters and labeled terminal strips.

d. Each control cabinet shall be provided with an integral heat exchanger capable of dissipating built up heat released from the associated controller and drive.

e. Every escalator shall be clearly and permanently marked on the controller with rated load and speed, braking torque, manufacture serial number, manufactured date, and the designated owner identification. Duplicate data plates for all motors, brakes and switches shall be mounted and labeled on the inside of the escalator controller.

7. Operating Devices:

a. Escalators shall have the provisions to be remotely stopped by the LCC. Appropriate conductors and controls shall be provided for future implementation.

b. Controls and Safety Devices - Operating controls:

1) Escalators shall be provided with a soft start feature to prolong the life of components.
2) Escalators shall have key-operated switches, accessible at both upper and lower landings, located on the exterior deck above the newel base. Alternate locations may be used subject to approval by Sound Transit.

3) Each keyed switch shall be clearly and permanently labeled, including starting and direction selection where escalators are reversible.

4) Interlocks shall be provided to bring the escalator to a smooth stop, in either direction of travel, before a change of direction may be made for reversible escalators.

5) The key switch shall be keyed to manufacturer’s standard key system.

8. Control Switchgear (Main): The main control switchgear of an escalator shall contain at least the following devices:

   a. Lockable main switch thermal and magnetic motor protection starter for up and down travel, hour counter, auxiliary contactors, phase failure device, phase sequence monitor and ground fault monitor.

   b. The indication shall be locked automatically. Reset shall be done by a separate switch installed in the controller. The emergency stop shall not be locked.

   c. All terminals shall have identification markings, and all cables shall be provided with cable markers.

   d. Relays shall be provided with visual indication that they are energized.

9. Step Drive Assembly: Direct or indirect drive. Machine sprockets at each side over which step chains or step chain rollers: pass and transmit motion from machine to steps. If indirect chain drive is used between machine and drive sprocket, provide emergency brake on drive assembly to automatically set if drive chain fails. Provide roller-type sealed bearings.

10. Stop Switch: Conform to Code

11. Remote Monitoring Interface: Provide an interface terminal strip mounted within the escalator controller for remote monitoring and control of each escalator by the Building Management System (BMS).

   a. Terminal strip shall be of sufficient size to receive all points specified below with additional space for future expansion of 4 points minimum.

   b. Terminal blocks: Accept No.14 AWG.

   c. Receive the following dry contact inputs to effect the following control actions for each escalator:

      1) Remote Stop.

   d. Provide normally open dry contacts for each of the following status items for each escalator:

      1) Escalator Running/Off
2) Escalator Traveling Up/Down
3) Escalator Fail
4) Escalator Emergency Stop Button
5) Seismic operation
6) Truss heater
7) Combplate heater

e. Provide conduit and wiring between the escalator pit, high water sensors and the interface terminal strip for remote monitoring by the Building Management System.

1) Provide normally open dry contact for the following status item for the pit:

   a) Sump High Water Alarm

<table>
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<th>Term Block Label</th>
<th>Type</th>
<th>Operation</th>
<th>Dry Contact Function</th>
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<td>Status</td>
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</table>

D. Wellway Equipment

1. Truss: Steel truss to safely carry entire load of escalator, including all components, all cladding, full-capacity live load and weight of exterior truss with a factor of safety according to Code. Engineer truss to carry the exterior cladding material according to design assuming a dead load of 10 psf. Provide clearly identified exterior cladding support attachment locations on exposed sides and bottom of the entire length of truss. Provide fire resistant galvanized sheet metal exterior cladding at manufacturer’s factory.

   a. The deflection of the loaded truss shall not exceed one-thousandth of the span under code required live load.

   b. In addition, design truss to carry the weight of Sound Transit provided signs and their associated structural support at located as shown on the
contract documents. Assume a dead load of 250 pounds for each sign located as shown on the contract documents.

c. Permanent identification shall be provided on the truss for the centerline at both ends of the escalator and in both transition curves.

d. Permanent mark reflecting track system working point distances shall be provided at both ends of the escalator trusses.

e. Field splices, connections and shims:
   1) Field splices shall be rigid and non-deforming, and shall maintain alignment.
   2) Field modification shall not compromise the required paint and corrosion protection.
   3) All shims shall be type 304 stainless steel.
   4) Support shims shall not exceed 2 inches.

2. Truss Extensions: Provide truss extensions at upper and/or lower landings as required and/or as shown in Contract Drawings. End support locations will not be adjusted to accommodate installer’s equipment.

3. Noise Control: Provide sound isolation within truss as required to limit noise levels relating to escalator equipment and its operation to no more than 55 Decibels (dBA), measured 3 feet above escalator at any point of its length.

4. Vibration Control: The support angles at both ends of the main truss shall be mounted on isolation pads to prevent transmission of noise and vibration to the building structure. Readjustment of the escalator alignment shall be possible at any time by means of jack bolts at the supports. An adjustable intermediate support with isolation shall be provided.

5. Drip Pans: Minimum 1/8-inch galvanized steel drip pans of oil-tight construction beneath pit, machine room, and entire length of trusses. Ensure drip pan is of sufficient strength to withstand the weight of maintenance personnel. Ensure pan extends full inside length and it’s wide enough to collect oil drips, water, dirt and anything dropped through the tracks; slope to drain. Provide suitable drains with grease trap at base of each oil pan with removable access plate to sump.

6. Oil Water Separator: For all outdoor or partially outdoor escalators, provide wellway with an oil water separator located at the lower pit.

7. Step Tracks:
   a. Construct from steel. Bolt sections of track, including transitions, to facilitate maintenance and replacement if required. Factory install and align track sections, including transitions, to ensure smooth, quiet operation of running gear under all conditions. Form a fully independent assembly consisting of the individual track section, together with transition section, step chain tension carriage, main drive shaft and handrail drive shaft.
   b. Tracks shall retain steps and running gear safely under load requirements and at the highest speed specified.
c. Sections of track shall be assembled together for easy removal and replacement of defective sections. The system shall be adjustable. Connecting of track sections by welding is not acceptable.

d. Design of mechanical components shall provide for easy installation and removal without the dismantling of parts of the structure.

e. The tracks shall be properly supported on trusses to provide correct alignment and smooth transition on return stations. The rolling surface of the passenger side track shall be a minimum thickness of 1/8 inch, return side track shall be a minimum thickness of 5/64 inch.

f. The guiding system for the step chains and step wheels shall be of zinc plated or galvanized steel profiles with smooth and even running surfaces and with the joints cut diagonally to the running direction. The guide profiles shall not be welded together at the joints.

g. A second, continuous guiding profile shall be provided above the step chain rollers so that the step chains are positively guided in the area of the escalator open to passengers.

8. Step Chains: Steel links with hardened pins connecting adjacent steps and engaging drive sprockets. Provide synthetic composition roller assemblies with sealed bearings. Provide escalator design that permits chain inspection and operation while unit is running with steps removed.

a. Step chain shall be water resistant, low lubrication or lube free, endless, roller-type with one on each side of the step.

b. Step chains shall be heat treated steel construction, supported at intervals by linkage wheels.

c. A means to prevent steps from coming into physical contact with one another and to prevent chains from sagging or buckling shall be provided.

d. A means to maintain constant distance between step axles shall be provided.

e. An automatic tensioning device to maintain tension under load and to compensate for wear shall be provided. The device shall be located within the truss at the lower end.

f. Step chain tensioning device:

1) The step chain tensioning device shall be of a design that keeps the step chains at the correct tension.

2) A pointer and scale shall be required provided to gauge step chain tensioning and wear.

3) Bearings, if used, shall be rated ABMA L10, 200,000

g. A means to maintain constant distance between step axles shall be provided.

h. Step chains shall be constructed to permit removal of segments as may be required for replacement purposes at a minimum of every six-axle section. Each escalator shall have at least two one-axle sections.
i. Support wheels spaced to distribute load and to guide linkage throughout the run shall be provided. Rollers shall be constructed of polyurethane material, with a diameter sufficient to provide reliability, maintainability, smoothness of motion and to operate within the noise level requirements specified. The chain rollers shall have polyurethane tires, sealed bearings and diameters of not less than 4 inches... They shall require no additional lubrication. The wheels, hubs and bearings shall have an L10 rating of 100,000 hours.

1) Wheels shall be affixed to permit rapid replacement.

j. Each pair of step chains shall be a matched set within manufacturing tolerances. Only precision, roller fishplate chains of high-grade heat-treated steel shall be used as step chains.

k. Step chain and chain pins shall have a surface pressure at engaging points that shall not exceed 30 N/mm² (3,450 psi). This is to be based on the step loads as defined in the step chain load requirement.

l. The safety factor shall be a minimum of 6.

m. A shielding device shall be provided to protect chain, track guides and rollers against water, dirt and debris

n. Step chain lubrication requirements:

1) All parts, requiring lubrication other than sealed items, shall be designed for an automatic or remote lubricating system. The system shall operate only when the escalator is running, and the amount of lubrication shall be fully adjustable. A reservoir with a low-oil signal shall be connected to the controller, and a minimum capacity capable of providing the OEM’s required lubrication for one month of operation based on the specific operating hours for this installation, shall be provided.

2) System shall be positive acting, located in the escalator pit.

3) A reservoir level indication shall be provided where lubricants are contained within housings, supply tanks and larger filler cups.

4) A means to maintain lubricant viscosity shall be provided when required.

o. Bearings:

1) Sealed bearings shall be used where possible.

2) Bearings requiring manual lubrication shall be furnished with fittings to accommodate the use of a pressure gun for lubrication.

3) Self-lubricating bearings or material other than ball or roller type.

4) Manual lubrication points shall be easily accessible and available.

9. Step Chain Tension Carriage: Spring tensioning device to take up chain slack and maintain constant tension.
10. Step Assembly: Single piece die-cast aluminum, fastened to the step chain axles. Provide cleated treads and risers. Cover the underside of Steps with sound-deadening material.

a. The steps shall carry the load under maximum concentric and eccentric loading conditions without failure.

b. Die-cast aluminum steps shall not have more than 0.3 percent copper content.

c. The Steps shall be designed to mesh with the combplates.

d. Step and various attachments shall permit removal of steps without disturbing the balustrades or decking.

e. The design shall permit the running of the drive without steps for convenience in cleaning and inspection.

f. Steps shall be constructed so as to be driven by step linkages to step or step rollers.

g. Step rollers shall have polyurethane tires in hubs, sealed roller bearings and a diameter of no less than three inches. Step rollers shall not require any additional lubrication and must be rated for severe, heavy-duty service. Step roller bearings shall have an L10 rating of 100,000 hours.

h. Safety demarcation lines or strips shall be provided in step treads to assist demarcation between treads when they are level at top and bottom landings. Provide contrasting color demarcation lines (yellow) on back edge and sides of treads.

i. The entire assembly shall be treated with not less than one coat of zinc chromate primer or iron phosphate and one coat of power coated enamel for corrosion resistance.

j. Washers and nuts shall be provided as follows:

1) Tap bolts: Lock washers

2) Through bolts: Lock nuts or approved equal

11. Safety Devices: Escalator safety devices shall comply with code requirements and include a safety brake activated if the step chains break or the step chain tension drops below a predetermined level; a power supply cutoff to stop the escalator if it overspeeds by some fixed percentage, provision for automatic stopping if the direction of travel is accidentally reversed; and provision for automatic stopping if the treads are separated from the comb plate or the interior skirt panels by a predetermined amount.

a. Use of SIL (Safety Integrity Level) rated devices for EPD (Electrical Protective Devices) where possible is preferred to traditional positively opened mechanical switches. These devices shall be listed/certified and labeled/marked to a SIL rating in accordance with the applicable requirements of IEC 61508-2 and IEC 61508-3 with a SIL rating equal to or greater than the SIL indicated for the applicable device shown in ASME A17.1.
b. The detection of a dangerous fault (e.g. with diagnostic tests, proof-tests, or by any other means) in SIL rated electrical/electronic/programmable electronic system (E/E/PES, or commonly referred to as "PES") that can tolerate a single fault shall cause the escalator to revert to a known fail-safe condition. Where necessary, to maintain the integrity of the SIL rated PES and maintain the fail-safe condition prior to a second fault that could lead to a dangerous condition, a manual reset shall be required to remove the SIL rated PES from the fail-safe condition.

c. Safety devices include—but are not limited to—those required by ASME A17.1 and those listed below:

1) Broken Step-Chain or Step Link Device: A broken step chain or step link device shall be provided to cause the interruption of power to the drive machine if a step chain or step link breaks.

2) Broken Drive Chain Device: When the driving machine is connected to the main drive shaft by a chain, a device shall be provided to cause the application of the brake on the main drive shaft if the drive chain breaks.

3) Skirt Obstruction Device: A device shall be provided to open the power circuit to the escalator driving machine motor and brake should an object become wedged between the step and the skirt panel as the step approaches either the upper or the lower landing.

4) Heavy duty skirt brushes mounted on the visible side of the skirting with tamper resistant brackets.

5) Reversal Stop Device: A device shall be provided to open the power circuit to the driving machine motor and operate the brake in case of accidental direction reversal while the escalator is operating in the ascending direction.

6) Automatic stop tied to fire alarm.

7) Step up-thrust;

8) Handrail speed;

9) Missing step;

10) Step level;

11) Handrail entry;

12) Combplate impact; and

13) Step demarcation UL rated lights suitable for wet locations.

14) Lockable stop switch or disconnect shall be provided in both pits of escalators.

15) A switch shall prevent operation of the escalator if any part of the combplate is not in place.
16) Speed Governor: A speed governor shall be provided to cause the interruption of power to the driving machine if the speed of the steps exceeds more than 40 percent above the rated speed.

17) Slide Prevention Device: Surface projections shall be provided on the surface of the outer decks between escalators or adjacent to walls to discourage patrons from sliding down the channels.

12. Electrical Wiring:
   a. Conductors: Copper throughout with individual wires coded and all connections identified on studs or terminal blocks. Type SO cable may be utilized for wiring conducting 30 Volts or less, in accordance with NEC 620-621.
   b. Conductors: 31 Volts rms or greater. Provide conduit, junction boxes, connections, and mounting means in accordance with requirements of Section 26 05 33, Raceways and Boxes for Electrical Systems. Provide painted or galvanized steel or aluminum conduit. Conduit size minimum 3/8 inch. Do not use flexible conduit exceeding 18 inches in length.
   c. Galvanized rigid pipe and/or liquid tight flexible metal conduit shall be used in the truss. Liquid tight flexible metal conduit must be CSA/UL approved.
   d. LSHF (low-smoke, halogen free) wiring shall be used where commercially available throughout the escalator installation.
   e. In Class 2 circuits, SO cord may be used in lengths not to exceed 3 feet.
   f. Liquid tight flexible metal conduit must be CSA/UL approved.
   g. PVC may not be used in the escalator installation.
   h. All fixtures shall be NEMA 4 where exposed to moisture.

13. Motors:
   a. The driving motors shall be AC induction motors with starters. Voltage 480 VAC, three phase, frequency 60 Hz.
   b. The motors shall be totally enclosed with external cooling fins.
   c. The motor protection class shall be equivalent to IP55 insulation group F.
   d. Driving motors and motor switchgear shall provide a smooth start.

2.04 COMPONENTS

A. Handrails

1. Design handrails for outdoor use. The handrail shall be a composite of either vulcanized rubber or an approved equal with a synthetic fabric slider, and shall be constructed with a steel cable tension member providing a minimum strength of 25 kN over the splice area. Provide white inserts in black handrail, at least one insert shall be visible at all times at the end returns of the handrail.
   a. Handrails shall receive their motion from the main escalator drive through direct gearing and drive shaft or drive chains, so that the
handrail and steps operate at the same speed in each direction of travel. Driving and guiding wheels shall have a groove to accept the wedge on the underside of the handrail. The handrail shall have a V-shape wedge.

b. A means to take up handrail slack using a tensioning device, where required, shall be located within escalators. In addition, a method of releasing the device for repair or removal of handrails shall be provided.

c. Newels shall be designed and constructed so that the handrail will return into the newel end at a point inconspicuous and difficult for passengers to reach.

d. Newel sheaves shall be provided at the upper and lower newels.

e. The handrail drive system and guides shall be designed and installed so that the handrail cannot be thrown off or disengaged while running and special design attention shall be given to the area where the handrail passes from the drive system to the guides.

f. Handrail rollers shall have sealed bearings rated at ABMA L10, 100,000 hours.

g. Friction drive sheaves and idlers shall be designed and positioned so that lubricant cannot reach the surface of the handrail. Marking and spotting of the handrail by drive equipment shall not be permitted. Provide sealed bearings rated at ABMA L10, 100,000 hours.

h. Handrail guides shall be:
   1) Continuous on the exposed portion of the handrails.
   2) Constructed of type 316 stainless steel.
   3) Shall not be subject to corrosion nor pitting.
   4) Shall have a polished or specially coated permanent finish to minimize frictional wear to the under surface of the handrail.
   5) On the unexposed portion, guiding shall be by adjustable rollers having sealed

i. Handrail gearbox, if provided, shall have bearings rated at ABMA L10, 200,000 hours.

B. Balustrade

1. Panels shall be a minimum of 1/8 inch solid type 316 stainless steel and backing panels, where used, shall be noncombustible and are subject to owner approval. Glass balustrades are not permitted.

2. Balustrades shall have no sharp edges or pinch points.

3. Panels shall be constructed, when practical, in equal lengths for interchangeability.

4. Panels shall be attached to permit easy removal for inspection, lubrication and adjustment of safety devices.
5. Panels shall be sized so that no more than two people are required to remove a panel, and without the aid of special handling equipment.

6. Requirements for exposed panel fasteners (where used): Panels shall be fastened to their respective supports or mating portions with tamperproof flathead machine screws.

7. When the framework to which panels are fastened is less than 1/4 inch thick, steel backup plates with a minimum 1/4 inch thickness shall be added. These plates shall have tapped holes or clearance holes where necessary.

8. Provide anti-slide devices on adjacent surfaces between escalators, stairs, or between escalator and walls to meet code.

   a. Skirt panels shall be a minimum of 1/8 inch thick solid type 316 stainless steel.

10. Deck Boards: Abut all deck section to one another to provide a smooth surface-to-surface connection with butt joint transition, top and bottom, and horizontal to inclined sections.
   a. Decking shall be a minimum of 1/8 inch thick solid type 316 stainless steel, identical in finish to balustrade.
   b. Decking between escalators shall be designed to support a live load of 175 lb./ft² without permanent deformation.
   c. Paneling, decking and other enclosures shall be supported on a steel frame.

11. Finishes:
   a. Interior Panels: Non-directional finish stainless steel reinforced vertical panels with section joints vertical to escalator incline, flush inclined panel from skirt to handrail guide above.

12. Trim and Moldings: Manufacturer’s standard finish.

13. Floor Intersection Guards: Provide clear Plexiglas intersection guards at floor penetrations as required according to Code.

14. Extended Newels: Align newels of adjacent escalators at upper and lower landings.

C. Landings

1. Flat Steps: Provide upper and lower landings with three flat steps.

2. Combplates Assembly: Aluminum or other alloy provided with non-slip surface. Provide removable comb sections. Combplates shall provide a visual contrast
with the steps either by color, pattern or texture. Provide combplate lighting in skirt panel on both sides of units at both upper and lower landings.

a. Complete assemblies of wear-resisting, noncorrosive metal material with exposed anti-slip surfaces shall be fabricated.
b. A separate switch for vertical and horizontal detection shall be provided.
c. Comb plate sections shall be removable to permit ease of replacement.
d. Provisions for lateral and vertical fine adjustments shall be provided so that cleats of step treads pass between comb teeth with minimum clearances.
e. Provide heaters for comb plate assemblies to eliminate buildup of ice.
f. Provide step demarcation lights at lower and upper ends of escalator immediately outbound of the combplate.

3. Landing Plates: Extruded or die-cast aluminum in a ribbed pattern transverse to the escalator axis. Ribs shall be designed to provide maximum traction, and finished to match combplates. Extend plates from combplates to equipment access plates at upper and lower ends. Extend plates full width of truss. At locations where two escalators are adjacent, provide separate landing plates designed to allow adjacent escalators to remain operational while work is being performed only one escalator.

a. Shall have type 316 stainless steel frames at floor openings, designed to be supported on truss heads.
b. Shall be reinforced, as necessary, to be rigid and able to withstand a live load of 250 lb. /feet$^2$ with zero permanent deformation.
c. Shall have exposed portions constructed of material and finish to harmonize with steps and combplates.

4. Equipment Access Plates: Aluminum or other alloy with non-slip surface. Provide removable access plates to provide for entry into equipment spaces at upper and lower ends. Cover entire truss openings with plates. Match access plate to material and finish of adjacent landing plates. Provide landing plate and access floor plate without visible manufacturers name or logo.

D. Signal and Control Fixtures

1. Provide upper and lower newel or stanchion-mounted operating stations. Mount on right side when facing unit. Match deck finish. Identify Function and operating positions of switches and buttons with engraved characters that are readily visible from a standing position. Include the following at each station:

a. Red emergency stop button. Cover the button with a transparent cover that can be readily lifted or pushed aside. When the cover is moved, ensure an audible warning signal is activated. Ensure the signal has a minimum sound intensity of 80 dBA at the button location. Engrave the cover EMERGENCY STOP; MOVE COVER or equivalent legend (for example LIFT COVER); and PUSH BUTTON. EMERGENCY STOP in letters not less than 1/2 inch high. Engrave other required wording in letters not less than 3/16 inch high. Ensure the cover is self-resetting.
1) Provide emergency stop buttons at upper and lower landings; stop/start buttons inaccessible to the public on site; and a status monitoring control panel that may be remotely monitored in the LCC.

2) Emergency stop buttons shall cause an alarm at the LCC when activated.

b. Key switch to start unit.

c. Key directional control switch.

d. Each keyed switch shall be clearly and permanently labeled, including starting and direction selection.

d. Interlocks shall be provided to bring the escalator to a smooth stop, in either direction of travel, before a change of direction may be made.

e. Engraved Washington State Department of Labor & Industries conveyance number and escalator number.

E. Skirt/Balustrade Lighting

1. Provide LED skirt or balustrade panel lighting along entire path of travel on both sides of the unit.

a. Elongated round fixtures composed of multiple LED lights and protective cover.

1) Combplate light fixture or similar

2) Fixtures spaced at 1 foot nominal interval

3) Lighting shall provide a minimum of 1 foot candle (FC) at all points along entire path of travel, at tread level under emergency conditions.

2.05 ACCESSORIES

A. Signs

1. Landing Signs: Provide caution signs at top and bottom landings according to Code, engraved plate with material and finish to match decking.

B. Key box

1. Provide a keybox with hooks suitable for storing all escalator keys. Locate within Fire Command Center room.

a. All keys necessary for access, resetting or technical adjustment of escalators shall be included.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Site Verification of Conditions
1. Prior to beginning the installation of equipment, examine wellway and pit areas. Verify that no irregularities exist that would affect quality of execution of work specified.

2. Do not proceed with installation until work in place conforms to Contract requirements.

3.02 INSTALLATION

A. Install all equipment in accordance with Manufacturer’s instructions, referenced codes, Contract Specifications, and approved Submittals.

B. Install all equipment for ease of maintenance.

C. Install all equipment to afford maximum accessibility, safety, and continuity of operation.

D. Replace or refurbish all material to meet performance requirements outlined in these Contract Specifications prior to station turnover for normal operation. There will be an extended period of time from the point that the escalators are installed to the final acceptance and station revenue service operation.

E. Remove oil, grease scale, and other foreign matter from the following equipment and apply one coat of field-applied machinery enamel.

   1. All exposed equipment and metal work installed as part of this work that does not have architectural finish.
   3. Neatly touch up damaged factory-painted surfaces with original paint and color. Protect machine-finish surfaces against corrosion.

F. Coordinate access and escalator work with work of other trades for proper time and sequence to avoid construction delays. Use benchmarks, lines, and levels designated by Contractor to ensure dimensional coordination of Work.

G. Warp finish floor to level with the escalator floor plates but do not lay floor around escalator openings until escalator has been installed. Coordinate as required for installation.

H. Inspect site and verify embedded items are provided and correctly installed.

I. In event of notice of delay for access to Work, site storage at Contractor’s facility will be required.

3.03 TRAINING

A. Provide 2-4 hour sessions of onsite training for Sound Transit representatives in the proper use, operations and daily maintenance of escalators. The training shall:

   1. Review emergency provisions, including emergency access and procedures to be followed at the time of failure in operation and other building emergencies.
   2. Train ST personnel in normal procedures to be followed in checking for sources of operational failures or malfunctions.
   3. Train Sound Transit personnel in escalator startup inspection requirements in accordance with ANSI A17.1 section 8.6.11.6.1 through 8.6.11.6.4
4. Provide written documentation and instructional materials describing operational procedures covered during training for Sound Transit use in training future personnel.

3.04 FIELD QUALITY CONTROL

A. Work at the jobsite will be checked during the course of installation. Full cooperation with reviewing personnel is mandatory. Accomplish corrective work required prior to performing further installation.

B. Have Code Authority acceptance inspection performed and complete corrective work.

3.05 ADJUSTING

A. Track alignment: Re-align factory installed tracks if required to ensure continuous four-point contact with step and chain rollers. Secure joints without gaps and file irregularities to a smooth surface.

B. Lubricate all equipment in accordance with Manufacturer’s instructions.

C. Adjust motors, brakes, controllers, stopping switches, and safety devices to achieve required performance levels.

D. Adjust brakes and controlled descent devices to stop escalator with variable load without toppling passengers. Drive machine brakes shall stop the down running escalator at a rate no greater than 3 feet/second/second.

E. Adjust handrail speed to coincide with step speed.

3.06 CLEANING

A. Keep work areas orderly and free from debris during progress of Contract. Remove packaging materials on a daily basis.

B. Remove all loose materials and filings resulting from work.

C. Clean machine room equipment, truss interior, and pit.

D. Clean balustrades, deck boards, skirt panels, operating and signal fixtures, and trim.

E. Before Substantial Completion, remove all protective coverings and wrapping.

3.07 DEMONSTRATION

A. General: Furnish labor, materials, and equipment necessary for tests. Notify Resident Engineer five days in advance when ready for final review of each escalator unit or group. Final Acceptance of installation will be made only after all field quality control reviews have been completed, identified deficiencies have been corrected, all Sound Transit’s information and certificates have been received, and the following items have been completed to satisfaction of the Resident Engineer.

1. Workmanship and equipment: Comply with these Contract Specifications.

2. Contract speed and performance comply with these Contract Specifications.

3. Performance of following is satisfactory:

   a. Starting and running

   b. Controlled descent
c. Stopping

d. Equipment noise levels

e. Signal and operating devices

f. Overall ride quality

g. Handrail speed

h. Safety devices

4. Test Results:

a. In all test conditions, obtain specified speed, handrail speed, controlled
descent performance, stopping, ride quality, and operation noise levels
to satisfaction of the Resident Engineer.

b. Temperature rise in windings limited to 50 degrees C above ambient.

B. Personnel, Equipment, and Instruments: Furnish personnel, equipment, and instruments
to perform required tests. The following instruments may be necessary to complete the
tests:

1. Multi-meter.
2. 500-volt Megger.
3. Alternating current voltmeter and ammeter.
4. Celsius-calibrated thermometers (two minimum).
5. Precision tachometer.
7. Test weights for brake test.

C. Operating Tests:

1. Overspeed Protection Device: Test by operating at rated speed, tripping
overspeed device manually.


3. Broken Drive Chain Devices: Test by operating at rated speed, tripping broken
chain device manually.

4. Insulation-Resistance Test: Test safety circuit and motor winding circuit at 500
volts. Minimum resistance to ground: 1 megohm.

5. Running Test: Submit certified copy of type test based on Item 320.6 of
ASME A17.2.3 - Guide for Inspection of Elevators, Escalators and Moving Walks.

6. Demonstrate functionality of all remote monitoring and control terminations at
ITC.

7. Sleep Mode: Test by verifying that the escalator meets the specified sequence of
operations.
D. Field Review Scheduling: Schedule progress and final equipment reviews with the Resident Engineer. Reply promptly, in writing, to corrective work indicated on the Resident Engineer's progress and/or final review reports, indicating status, schedule for completion, and questions, diagnosis, and troubleshooting of escalator system.

END OF SECTION
SECTION 21 05 00
COMMON WORK RESULTS FOR FIRE SUPPRESSION

PART 1 - GENERAL

1.01 SUMMARY
   A. Work includes complete Fire Protection systems indicated on the drawings and this division’s specifications. The Contract Documents and General Requirements of the specification are a part of this division of the specification.

1.02 REFERENCES
   A. Definitions
      1. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe chases, unheated spaces immediately below roof, space above ceilings, unexcavated spaces, crawlspaces, and tunnels.
      2. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
      3. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
      4. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in chases.
      5. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
   B. Reference Standards: This Section incorporates by reference the revisions of the following documents as approved by the Authority Having Jurisdiction and as indicated in the contract documents.
      2. International Building Code (IBC)
      3. International Fire Code (IFC)
      4. National Fire Protection Association (NFPA) 13 and 14

1.03 ADMINISTRATIVE REQUIREMENTS
   A. COOPERATION WITH OTHER TRADES
      1. Give full cooperation to other trades and furnish in writing to other trades, with copies to the Resident Engineer, any information necessary to permit the work of all trades to be installed satisfactorily and with the least possible interference or delay.
2. Where Fire Protection work will be installed in close proximity to, or will interfere with work of other trades, assist in working out space conditions to make a satisfactory adjustment. If work is installed before coordinating with other trades, or if it causes any interference with work of other trades, make the necessary changes in the work to correct the conditions and bear all costs.

3. Furnish to other trades necessary templates, patterns, setting drawings and shop details for the proper installation of work and for coordinating adjacent work. This includes participation and support of any Building Information Modeling efforts associated with this contract.

1.04 SUBMITTALS

A. Submittals – As specified in this division’s specifications.

1. Drawings

   a. Drawings are diagrammatic, indicating the general arrangement of systems and work. Examine the architectural drawings for exact location of fixtures and equipment. Where they are not definitely located, obtain this information from the Resident Engineer.

   b. Follow drawings in laying out work and check drawings of other trades to verify spaces in which work will be installed. Maintain maximum headroom. If space conditions appear inadequate, notify the Resident Engineer before proceeding with the work. Make reasonable modifications in the work without extra cost as needed to prevent conflict with work of other trades and for proper execution of the work.

2. Product Data: For each type of product indicated.

3. Fire Department Connection, sign layout drawings for each location.

4. Schedules: Submit valve schedule for each piping system, typewritten and reproduced on 8-1/2 by 11-inch bond paper for mounting. Tabulate valve number, piping system, system abbreviations as shown on tag, location of valve, and variations for identification. Mark valves that are intended for emergency shut-off and similar special uses with “flags” in the margin of schedule. In addition to mounted copies, furnish copies as required for maintenance manuals.

5. Samples: Submit samples of each color, lettering style, and other graphic representation required for each identification material or system.

6. Documentation

   a. Provide as-built drawings of all building plans in accordance to Division 01 As-Built Documents specification. As-Built drawings shall include as a minimum the location and performance data on each piece of equipment, general configuration of pipe distribution system, including sizes, and water design flow rates of the actual installation. As-Built drawings shall also incorporate any work which deviates from the contract drawings, including changes resulting from addenda, Requests for Information, and Change Orders. Neatly draft changes on clean “hard copy” drawings to show the work clearly in the actual locations as built.

7. Operating Instructions

   Provide operating and maintenance instructions in accordance with Division 01 Operation and Maintenance Data specification.
8. The training of the appropriate maintenance staff for each equipment type and/or system shall include, as a minimum, the following:
   a. System/Equipment overview (what it is, what it does and which other systems and/or equipment does it interface with).
   b. Review of the available operations and maintenance (O&M) materials in accordance with Division 01 Operation and Maintenance Data specification.
   c. Review of the Record Drawings on the subject system/equipment, including valve schedules and zone distribution.
   d. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and startup procedures.

1.05 QUALITY ASSURANCE

A. MATERIAL AND WORKMANSHIP
   1. Materials and equipment required for the work shall be new and shall be furnished, delivered, erected, installed, connected, and finished in every detail; and shall be selected and arranged to fit properly into the building spaces. Where no specific kind or quality of material is given, an article as approved by the Resident Engineer shall be provided.
   2. Furnish the services of an experienced superintendent, who shall be constantly in charge of the work.
   3. Equipment and materials shall be installed with the approval of the Resident Engineer in accordance with the recommendations of the manufacturer. This includes the performance of such tests as the manufacturer recommends.

B. ACCESSIBILITY
   1. Install the work with adequate clearances throughout the project, including being responsible for the sufficiency of the size of shafts, chases, double partitions, and suspended ceilings. Such spaces and clearances shall be kept to the minimum size required.
   2. Locate all equipment that must be serviced, operated, or maintained in fully accessible positions. Minor deviations from drawings may be made to allow for better accessibility and any change shall be approved by the Resident Engineer.
   3. The Fire Protection Subcontractor shall provide the General Contractor the exact locations of access panels for each concealed valve, or other device requiring service. Access panels will be provided and installed by the General Contractor and as specified in the other divisions of the specifications. Submit locations of these panels to the General Contractor in sufficient time to be installed in the normal course of work.

1.06 DELIVERY STORAGE AND HANDLING

A. Deliver materials and equipment in original, sealed containers or packages in an undamaged condition complete with labels and instructions for handling, storing, unpacking, protection and installing.
B. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

C. Cleaning
1. Promptly remove waste material and rubbish caused by the work. At the completion of the work, clean the dirt and debris from the fire suppression installation, including equipment, and piping.

1.07 FIELD CONDITIONS

A. Electrical Connections
1. The power wiring and control wiring associated with fire suppression elements shall be coordinated and provided by the Contract. Motors and equipment shall be provided for current characteristics as indicated on the electrical drawings and be coordinated within the Contract to ensure proper function.
2. Provide control and electrical wiring details including power supply connections for any dry systems requiring power and control or any electrically activated valves that require interface with control systems.

B. Cutting and Patching
1. Provide drilling, coring, cutting, and patching necessary to install the work specified in this division. Patching shall match adjacent surfaces.
2. No structural members shall be cut without the approval of the Resident Engineer, and cutting shall be done in a manner directed by him. Do not damage or endanger any portion of the project or work of the Owner or any other separate contractor by drilling, coring, cutting, patching, excavating, and backfilling.
3. Inform the General Contractor and other subcontractors affected of requirements for cutting and patching.

C. Boxes, Sleeves, and Chase
1. Inform the General Contractor of requirements for boxes, sleeves, and chases. The General Contractor shall set boxes, sleeves, and chases. Furnish General Contractor with the boxes and sleeves and be responsible for informing General Contractor of required location.

1.08 WARRANTY

A. All work, materials, and equipment to be free from defects as required in Division 00 Procurement and Contracting Requirements.

B. The warranty disregards shorter time limits by any manufacturer of equipment provided.

C. Make all necessary adjustments and corrections during first year of operation. The fact that the Resident Engineer was present during any construction does not relieve the Contractor from responsibility for defects discovered after completion of the work.
PART 2 - PRODUCTS

2.01 EQUIPMENT LABELS

A. Metal Labels for Equipment

1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware if the label is to be mounted with fasteners.

2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 inches by 3/4 inch.

3. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.


5. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

B. Label Content: Include equipment’s Contract Drawing designation or unique equipment number, Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specification Section number and title where equipment is specified.

C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2 by 11-inch bond paper. Tabulate equipment identification number and identify Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specifications Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.02 VALVE TAGS

A. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.

1. Tag Material: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.

2. Valve Tag Size and Shape

a. 1-1/2 inches round

3. Fasteners: Brass wire-link or beaded chain

2.03 WARNING SIGNS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.

1. Letter Color: Red

2. Background Color: White

B. Maximum Temperature: Able to withstand temperatures up to 160 degrees F
C. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 inches by 3/4 inch

D. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

E. Fasteners: Stainless-steel rivets or self-tapping screws

F. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate

G. Label Content: Include caution and warning information, plus emergency notification instructions.

2.04 PIPE MARKERS

A. General Requirements for Manufactured Pipe Markers: Preprinted, color-coded, with lettering indicating service.

B. Pretensioned Pipe Markers: Precoiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive

C. Self-Adhesive Pipe Markers: Printed plastic with contact-type, permanent-adhesive backing

D. Pipe Markers Contents: Include identification of piping service using same designations or abbreviations as used on Contract Drawings, pipe size, and an arrow indicating flow direction:
   1. Lettering Size: At least 1-1/2 inches high
   2. Pipe Label Color Schedule:
      1. Fire Suppression Piping:
         a) Background Color: White.
         b) Letter Color: Red.

2.05 FIRE DEPARTMENT CONNECTION SIGNS

A. Provide signs at all fire department connections including pumping pressures and zones in accordance with Contract Drawings.

2.06 STANDPIPE VALVE IDENTIFICATION SIGNS

A. General Requirements for Standpipe Valve Identification Signs

1. Signs composed of 10-gauge aluminum sheet metal with 3M Diamond Grade DG reflective sheeting, ASTM Type XI or approved equal.

2. Copy to be 3 inches in height, “Clearview” regular font, all capitals. Red reflective letters on white reflective background.

3. Sign size to be 4-1/2 inches in height by required length.

4. Drill for two 1/4-inch-diameter stainless steel fasteners.
B. Sample sign face: E05-FHV-13  E05-IVLV-04

PART 3 - EXECUTION

3.01 INSTALLATION

A. Piping Systems

1. Contract Drawing, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

2. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.

3. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

4. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

5. Install piping to permit valve servicing.

6. Install piping at indicated slopes.

7. Install piping free of sags and bends.

8. Install fittings for changes in direction and branch connections.

9. Install piping to allow application of insulation, when applicable.

10. Select system components with pressure rating equal to or greater than system operating pressure.

11. Install escutcheons for penetrations of finished walls, ceilings, and floors.

12. Install floor plates for piping penetrations of equipment-room floors. Install floor plates with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.

13. Verify final equipment locations for roughing-in.

14. Install flexible expansion joints where indicated on drawings and where piping crosses building seismic joints. Install vertical support hanger within 4 pipe diameters on each side of the flexible joints and seismic joint. Brace each hanger longitudinally and transversely. Install vertical support at 180-degree return bend.

B. Equipment

1. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.
2. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

3. Install fire suppression equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.

4. Install equipment to allow right of way for piping installed at required slope.

C. Construction

1. Join pipe and fittings according to the following requirements.

2. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

3. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
   a. Threaded Joints: Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
      1) Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
      2) Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.

4. Soldered Joints: Apply water-flushable flux, unless otherwise indicated, to tube end. Construct joints using lead-free solder alloy.


   a. Damaged Threads: Do not use pipe sections that have cracked or open welds.

7. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

D. Pipe Connections: Make connections according to the following, unless otherwise indicated:

1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.

2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.

3. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

4. Underground, Exterior-Wall Penetrations: Install dielectric couplings and isolating flange gaskets for all underground piping connection the above piping. Coordinate locations and installation with corrosion control systems.
3.02 PREPARATION FOR IDENTIFICATION INSTALLATION
   A. Clean piping and equipment surfaces of substances that could impair bond of iden-
      tification devices, including dirt, oil, grease, release agents, and incompatible
      primers, paints, and encapsulants.
   B. Coordinate installation with piping insulation and heat trace installation as required.

3.03 EQUIPMENT LABEL INSTALLATION
   A. Install or permanently fasten labels on each major item of fire suppression equip-
      ment.
   B. Locate equipment labels where accessible and visible.

3.04 VALVE TAG INSTALLATION
   A. Install tags on valves in fire suppression piping systems.

3.05 PIPE MARKER INSTALLATION
   A. Locate pipe marker where piping is exposed or above accessible ceilings in finished
      spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and
      plenums; and exterior exposed locations as follows:
      1. Near each valve and device.
      2. Near each branch connection, excluding short takeoffs for sprinklers.
      3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
      4. At access doors, manholes, and similar access points that permit view of
         concealed piping.
      5. Near major equipment items and other points of origination and termination.
      6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25
         feet in areas of congested piping and equipment.
      7. On piping above removable acoustical ceilings. Omit intermediately spaced
         labels.

3.06 STANDPIPE VALVE IDENTIFICATION SIGNS
   A. Mount signs adjacent to valves with two 1/4-inch-diameter stainless steel fasteners and
      within 24 inches of valve and between 48 and 66 inches above floor height.

3.07 CONCRETE BASES
   A. Anchor equipment to concrete base according to equipment manufacturer’s written
      instructions and according to Authority having Jurisdiction and Seismic Codes.
      1. Construct concrete bases of dimensions indicated, but not less than 4 inches
         larger in both directions than supported unit.
      2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise
         indicated, install dowel rods on 18-inch centers around the full perimeter of the
         base.
      3. Install Type 304 stainless steel expansion anchors for supported equipment that
         extends through concrete base, and anchor into structural concrete floor.
4. Place and secure anchorage devices. Use supported equipment manufacturer’s setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

5. Install anchor bolts to elevations required for proper attachment to supported equipment.

6. Install anchor bolts according to anchor-bolt manufacturer’s written instructions.

7. Use 3,000-psi, 28-day compressive-strength concrete and reinforcement.

END OF SECTION
SECTION 21 05 17
SLEEVES AND SLEEVE SEALS FOR FIRE PIPING

PART 1 - PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Sleeves.
   2. Stack-sleeve fittings
   3. Sleeve-seal systems
   4. Sleeve-seal fittings
   5. Grout

1.02 REFERENCES

A. ASTM A53
B. ASTM E84/E814
C. ASTM C1107
D. ASME B36.10
E. UL (FRD) – Fire Resistance Directory

1.03 SUBMITTALS

A. Product Data: For each type of product indicated

PART 2 - PRODUCTS

2.01 SLEEVES

A. Cast-Iron Wall Pipe Sleeves: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

B. Galvanized-Steel Wall Pipes: ASTM A 53/A 53M, Schedule 40, with plain ends and welded steel collar; zinc coated.

C. Galvanized-Steel-Pipe Sleeves: ASTM A53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.

D. Galvanized-Steel-Sheet Sleeves: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.
2.02 STACK-SLEEVE FITTINGS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   2. Wade
   3. Zurn

B. Description: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing.
   1. Underdeck Clamp: Clamping ring with setscrews.

2.03 SLEEVE-SEAL SYSTEMS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Advance Products & Systems, Inc.
   2. CALPICO, Inc.
   3. The Metraflex Company.
   4. Pipeline Seal and Insulator, Inc.
   5. Link-Seal - GPT an EnPro Industries, Inc.

B. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
   1. An assembly consisting of a stainless steel frame, a compression mechanism, and insert modules for pipe, duct and tubing.
   2. Comply with F- and T-ratings as required by local codes, code official, and as tested in accordance with ASTM E814 or UL1479.
   3. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
   4. Designs should be water and gas tight to 14.5 psi.
      a. Seals shall be asbestos free, lead free, halogen free.
      b. Pressure Plates: Stainless steel.
      c. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements.

2.04 SLEEVE-SEAL FITTINGS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
1. HoldRite
2. The Metraflex Company.
3. Pipeline Seal and Insulator, Inc.

B. Description: Manufactured plastic, sleeve-type, waterstop assembly made for imbedding in concrete slab or wall. Unit has plastic or rubber waterstop collar with center opening to match piping OD.

2.05 GROUT
B. Characteristics: Nonshrink; recommended for interior and exterior applications.
C. Design Mix: 5000-psi, 28-day compressive strength.
D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION
3.01 SLEEVE INSTALLATION
A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls. Provide appropriate waterproofing when penetrating exterior envelope.
B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1-inch annular clear space between piping and concrete slabs and walls.
   1. Sleeves are not required for core-drilled holes.
C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
   1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
   2. Cut sleeves to length for mounting flush with both surfaces.
      a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.
   3. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.
D. Install sleeves for pipes passing through interior partitions.
   1. Cut sleeves to length for mounting flush with both surfaces.
   2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
   3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with applicable codes and standards requirements for joint sealants.
E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

3.02 STACK-SLEEVE-FITTING INSTALLATION
A. Install stack-sleeve fittings in new slabs as slabs are constructed.
   1. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
   2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with requirements applicable codes and standard for flashing.
   3. Install section of pipe to extend sleeve to 2 inches above finished floor level.
   4. Extend sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
   5. Using grout, seal the space around outside of stack-sleeve fittings.
B. Fire-Barrier Penetrations: Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

3.03 SLEEVE-SEAL-SYSTEM INSTALLATION
A. Install sleeve-seal systems in sleeves in exterior concrete walls above and below grade and slabs-on-grade at service piping entries into building.
   B. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.
   C. Fire-Barrier Penetrations: Maintain indicated fire rating of wall, floor at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

3.04 SLEEVE-SEAL-FITTING INSTALLATION
A. Install sleeve-seal fittings in new walls and slabs as they are constructed.
   B. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.
   C. Secure nailing flanges to concrete forms.
   D. Using grout, seal the space around outside of sleeve-seal fittings.
   E. Fire-Barrier Penetrations: Maintain indicated fire rating of wall, floor at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

3.05 SLEEVE SCHEDULE
A. Use sleeves for the following piping-penetration applications:
1. Exterior Concrete Walls above Grade:
   a. Piping Smaller Than NPS 6: Cast-iron wall sleeves.
   b. Piping NPS 6 and Larger: Cast-iron wall sleeves.

2. Exterior Concrete Walls below Grade:
   a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.
      1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
   b. Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.
      1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

3. Concrete Slabs-on-Grade:
   a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.
      1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
   b. Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.
      1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

4. Concrete Slabs above Grade:
   b. Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves Stack-sleeve fittings.

5. Interior Partitions:

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for materials and installation common to most piping systems including dielectric fittings, mechanical sleeve seals, sleeves, escutcheons, grout, equipment, concrete bases, and supports and anchorages.

1.02 REFERENCES

A. Definitions

1. Finished Spaces: Spaces other than plumbing and electrical equipment rooms, furred spaces, pipe chases, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspace, and tunnels.

2. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and plumbing equipment rooms.

3. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

4. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in chases.

5. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

B. Reference Standards: This Section incorporates by reference the revisions of the following documents as approved by the Authority Having Jurisdiction and as indicated in the contract documents.

1. American Society of Mechanical Engineers (ASME)
   a. ASME B1.20.1 Pipe Threads, General Purpose (Inch)

2. ASTM International (ASTM)
   a. ASTM B32 Standard Specification for Solder Metal
   b. ASTM B813 Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
   c. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
   d. ASTM C1107 Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
3. American Welding Society (AWS)
   a. AWS A5.8 Specification for Filler Metals for Brazing and Braze Welding
   b. AWS D1.1 Errata for Structural Welding Code – Steel
   c. AWS D10.12 Guide for Welding Mild Steel Pipe

1.03 ADMINISTRATIVE REQUIREMENTS

A. Coordination
   1. Provide control and electrical wiring details including power supply connections for any dry systems requiring power and control or any electrically activated valves that require interface with control systems.
   2. Drawings are diagrammatic, indicating the general arrangement of systems and work. Examine the architectural drawings for exact location of fixtures and equipment. Where they are not definitely located, obtain this information from the Resident Engineer.

   a. Follow drawings in laying out work and check drawings of other trades to verify spaces in which work will be installed. Maintain maximum headroom. If space conditions appear inadequate, notify the Resident Engineer before proceeding with the work. Make reasonable modifications in the work without extra cost as needed to prevent conflict with work of other trades and for proper execution of the work.

B. Cooperation with other trades
   1. Give full cooperation to other trades and furnish in writing to other trades, with copies to the Resident Engineer, any information necessary to permit the work of all trades to be installed satisfactorily and with the least possible interference or delay.
   2. Where plumbing work will be installed in close proximity to, or will interfere with work of other trades, assist in working out space conditions to make a satisfactory adjustment. If work is installed before coordinating with other trades, or if it causes any interference with work of other trades, make the necessary changes in the work to correct the conditions and bear all costs.
   3. Furnish to other trades necessary templates, patterns, setting drawings and shop details for the proper installation of work and for coordinating adjacent work. This includes participation and support of any Building Information Modeling efforts associated with this contract.

1.04 SUBMITTALS

A. Submittals – As specified in this division’s specifications.
   1. Drawings
   2. Drawings are diagrammatic, indicating the general arrangement of systems and work. Examine the architectural drawings for exact location of fixtures and
equipment. Where they are not definitely located, obtain this information from the Resident Engineer.

a. Follow drawings in laying out work and check drawings of other trades to verify spaces in which work will be installed. Maintain maximum headroom. If space Ma conditions appear inadequate, notify the Resident Engineer before proceeding with the work. Make reasonable modifications in the work without extra cost as needed to prevent conflict with work of other trades and for proper execution of the work.

3. Product Data: For each type of product indicated.

4. Fire Department Connection, sign layout drawings for each location.


6. Schedules: Submit valve schedule for each piping system, typewritten and reproduced on 8-1/2 by 11-inch bond paper for mounting. Tabulate valve number, piping system, system abbreviations as shown on tag, location of valve, and variations for identification. Mark valves that are intended for emergency shut-off and similar special uses with “flags” in the margin of schedule. In addition to mounted copies, furnish copies as required for maintenance manuals.

7. Samples: Submit samples of each color, lettering style, and other graphic representation required for each identification material or system.

8. Documentation

B. Provide as-built drawings of all building plans in accordance to Division 01 As-Built Documents specification. As-Built drawings shall include as a minimum the location and performance data on each piece of equipment, general configuration of pipe distribution system, including sizes, and water design flow rates of the actual installation. As-Built drawings shall also incorporate any mechanical work which deviates from the contract drawings, including changes resulting from addenda, Requests for Information, and Change Orders. Neatly draft changes on clean “hard copy” drawings to show the work clearly in the actual locations as built.

1. Operating Instructions

a. Provide operating and maintenance instructions in accordance with Division 01 Operation and Maintenance Data specification. The training of the appropriate maintenance staff for each equipment type and/or system shall include, as a minimum, the following:

b. System/Equipment overview (what it is, what it does and which other systems and/or equipment does it interface with).

c. Review of the available operations and maintenance (O&M) materials in accordance with Division 01 Operation and Maintenance Data specification.

d. Review of the Record Drawings on the subject system/equipment, including valve schedules and zone distribution.

e. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and startup procedures.
1.05 QUALITY ASSURANCE

A. Material and Workmanship

1. Materials and equipment required for the work shall be new and shall be furnished, delivered, erected, installed, connected, and finished in every detail; and shall be selected and arranged to fit properly into the building spaces. Where no specific kind or quality of material is given, an article as approved by the Resident Engineer shall be provided.

2. Furnish the services of an experienced superintendent, who shall be constantly in charge of the work.

1.06 DELIVERY, STORAGE AND HANDLING

A. Deliver pipes and tubes with factory-applied end caps. Maintain end caps through shipping, storage and handling to prevent pipe end damage and to prevent entrance of dirt, debris, and moisture.

B. Store plastics pipes away from direct sunlight. Support to prevent sagging and bending.

C. Accessibility

1. Install the work with adequate clearances throughout the project, including being responsible for the sufficiency of the size of shafts, chases, double partitions, and suspended ceilings. Cooperate with other trades where work is in the same space. Such spaces and clearances shall be kept to the minimum size required.

2. Locate all equipment that must be serviced, operated, or maintained in fully accessible positions.

3. The Fire Protection Subcontractor shall provide the General Contractor the exact locations of access panels for each concealed valve, or other device requiring service. Access panels will be provided and installed by the General Contractor and as specified in the other divisions of the specifications. Submit locations of these panels to the General Contractor in sufficient time to be installed in the normal course of work.

1.07 FIELD CONDITIONS

A. Cutting and patching

1. Provide drilling, coring, cutting, and patching necessary to install the work specified in this division. Patching shall match adjacent surfaces.

2. No structural members shall be cut without the approval of the Resident Engineer, and cutting shall be done in a manner directed by them. Do not damage or endanger any portion of the project or work of the Owner or any other separate contractor by drilling, coring, cutting, patching, excavating, and backfilling.

3. Inform the General Contractor and other subcontractors affected of requirements for cutting and patching.

B. Boxes, Sleeves and Chases

1. Inform the General Contractor of requirements for boxes, sleeves, and chases. The General Contractor shall set boxes, sleeves, and chases. Furnish General
Contractor with the boxes and sleeves and be responsible for informing General Contractor of required location.

1.08 RECORD DOCUMENTATION

A. As-built drawings shall include as a minimum the location and performance data on each piece of equipment, general configuration of pipe distribution system, including sizes, and water design flow rates of the actual installation. As-built drawings shall also incorporate any mechanical work which deviates from the contract drawings, including changes resulting from addenda, Requests for Information, and Change Orders. Neatly draft changes on clean “hard copy” drawings to show the work clearly in the actual locations as built.

1.09 WARRANTY

A. All work, materials, and equipment to be free from defects as required in Division 09 Procurement and Contracting Requirements.

B. The warrant disregards shorter time limits by any manufacturer of equipment provided.

C. Make all necessary adjustments and corrections during first year of operation. The fact that the Resident Engineer was present during any construction does not relieve the Contractor from responsibility for defects discovered after completion of the work.

1.10 OPERATING INSTRUCTIONS

A. Provide operating and maintenance instructions in accordance with Division 01 Operation and Maintenance Data specification

1. System/Equipment overview (what it is, what it does and which other systems and/or equipment does it interface with).

2. Review of the available operations and maintenance (O&M) materials in accordance with Division 01 Operation and Maintenance Data specification.

3. Review of the Record Drawings on the subject system/equipment, including valve schedules and zone distribution.

4. Hands-on demonstration of all normal maintenance procedures, normal operating modes, and all emergency shutdown and startup procedures.

PART 2 - PRODUCTS

2.01 JOINING MATERIALS

A. Manufacturers


2. Central Plastics Company


5. Or approved equal

B. Description
1. Fittings are to be the same size and compatible with the piping to be joined. Pressure rating for fittings shall at least be equal to the piping that is to be joined.

C. Materials

1. Unless indicated otherwise the following shall be used as joining materials for plumbing work:
   a. Pipe-Flange Gasket Materials: nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.
   b. See other sections for isolating flange gasket kits.
   c. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.
   d. Solder Filler Metals: lead-free alloys.
   e. Brazing Filler Metals: BCuP Series or BAg1, unless otherwise indicated
   f. Solvent Cements for Joining Plastic Piping
      1) CPVC Piping: ASTM F493
      2) PVC Piping: ASTM D2564. Include primer according to ASTM F656

2.02 DIELECTRIC FITTINGS

A. Description

1. Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.

B. Performance

1. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 degrees F.
2. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 degrees F.
3. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 300-psig minimum working pressure as required to suit system pressures.
4. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 degrees F.
5. Dielectric Nipples: Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 300-psig minimum working pressure at 225 degrees F.

C. Material

1. Suitable for system fluid, pressure, and temperature.
2.03 FLOOR PLATES
A. Description
1. One-Piece Floor Plates: Cast iron flange with holes for fasteners.

2.04 FLEXIBLE EXPANSION JOINT FOR VENT AND ROOF DRAIN PIPING
A. Description
1. Flexible loop capable of 4-inches movement in three planes and consisting of two flexible sections of hose and stainless steel braid, two 90-degree bends and one 180-degree return bend with hanger support nut and drain/air release plug. Provide MetraFlex Metraloop or equal.
2. Performance
   a. 150 psi rated

2.05 ACCESS PANELS
A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Croker FRP
   2. Mifab
B. Description
   1. Manufactured stainless steel access panel to provide access to utilities in walls and ceilings
   2. Dimensions: Scheduled
C. Assembly or Fabrication
   1. Continuous hinge with universal latch. Material shall be minimum 16-gauge door and frame and shall be listed for fire rated applications

PART 3 - EXECUTION
3.01 INSTALLATION
A. Piping Systems
   1. Contract Drawing, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.
   2. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.
3. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

4. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

5. Install piping to permit valve servicing.

6. Install piping at indicated slopes.

7. Install piping free of sags and bends.

8. Install fittings for changes in direction and branch connections.

9. Install piping to allow application of insulation, when applicable.

10. Select system components with pressure rating equal to or greater than system operating pressure.

11. Install escutcheons for penetrations of finished walls, ceilings, and floors.

12. Install floor plates for piping penetrations of equipment-room floors. Install floor plates with ID to closely fit around pipe, tube, and insulation of piping and with OD that completely covers opening.

13. Verify final equipment locations for roughing-in.

14. Install flexible expansion joints where indicated on drawings and where piping crosses building seismic joints. Install vertical support hanger within 4 pipe diameters on each side of the flexible joints and seismic joint. Brace each hanger longitudinally and transversely. Install vertical support at 180-degree return bend.

B. Equipment

1. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.

2. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.

3. Install fire suppression equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.

4. Install equipment to allow right of way for piping installed at required slope.

C. Construction

1. Join pipe and fittings according to the following requirements.

2. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

3. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

   a. Threaded Joints: Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows:
1) Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.

2) Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged.

4. Soldered Joints: Apply water-flushable flux, unless otherwise indicated, to tube end. Construct joints using lead-free solder alloy.


   a. Damaged Threads: Do not use pipe sections that have cracked or open welds.

7. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

D. Pipe Connections: Make connections according to the following, unless otherwise indicated:
   1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
   2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.
   3. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.
   4. Underground, Exterior-Wall Penetrations: Install dielectric couplings and isolating flange gaskets for all underground piping connection the above piping. Coordinate locations and installation with corrosion control systems.

3.02 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

B. Coordinate installation with piping insulation and heat trace installation as required.

3.03 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of fire suppression equipment.

B. Locate equipment labels where accessible and visible.

3.04 VALVE TAG INSTALLATION

A. Install tags on valves in fire suppression piping systems.
3.05 PIPE MARKER INSTALLATION

A. Locate pipe marker where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and device.
2. Near each branch connection, excluding short takeoffs for sprinklers.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.

3.06 STANDPIPE VALVE IDENTIFICATION SIGNS

A. Mount signs adjacent to valves with two 1/4-inch-diameter stainless steel fasteners and within 24 inches of valve and between 48 and 66 inches above floor height.

3.07 CONCRETE BASES

A. Anchor equipment to concrete base according to equipment manufacturer’s written instructions and according to Authority having Jurisdiction Seismic Codes.

1. Construct concrete bases of dimensions indicated, but not less than 4 inches larger in both directions than supported unit.
2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of the base.
3. Install Type 304 stainless steel expansion anchors for supported equipment that extends through concrete base, and anchor into structural concrete floor.
4. Place and secure anchorage devices. Use supported equipment manufacturer’s setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
5. Install anchor bolts to elevations required for proper attachment to supported equipment.
6. Install anchor bolts according to anchor-bolt manufacturer’s written instructions.
7. Use 3,000-psi, 28-day compressive-strength concrete and reinforcement.

END OF SECTION
SECTION 22 05 17  
SLEEVES AND SLEEVE SEALS FOR PLUMBING

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Sleeves
   2. Stack-sleeve fittings
   3. Sleeve-seal systems
   4. Sleeve-seal fittings
   5. Grout

1.02 REFERENCES

A. ASTM A53
B. ASTM E84/E814
C. ASTM C1107
D. ASME B36.10
E. UL (FRD) – Fire Resistance Directory

1.03 SUBMITTALS

A. Product Data: For each type of product indicated

PART 2 - PRODUCTS

2.01 SYSTEMS / ASSEMBLIES / MANUFACTURED UNITS / EQUIPMENT / COMPONENTS / PRODUCT TYPES

A. SLEEVES

   1. Cast-Iron Wall Pipe Sleeves: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

   2. Galvanized-Steel Wall Pipes: ASTM A 53/A 53M, Schedule 40, with plain ends and welded steel collar; zinc coated.

   3. Galvanized-Steel-Pipe Sleeves: ASTM A53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends and welded steel collar.

   4. Galvanized-Steel-Sheet Sleeves: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.
B. STACK-SLEEVE FITTINGS

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. Wade
   c. Zum

2. Description: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing.
   a. Underdeck Clamp: Clamping ring with setscrews.

C. SLEEVE-SEAL SYSTEMS

1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   a. Advance Products & Systems, Inc.
   b. CALPICO, Inc.
   c. Metraflex Company (The).
   d. Link-Seal.
   e. Pipeline Seal and Insulator, Inc.
   f. Proco Products, Inc.

2. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
   a. An assembly consisting of a stainless steel frame, a compression mechanism, and insert modules for pipe, duct and tubing.
   b. Comply with F- and T-ratings as required by local codes, code official, and as tested in accordance with ASTM E814 or UL1479.
   c. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
   d. Designs should be water and gas tight to 14.5 psi.
   e. Seals shall be asbestos free, lead free, halogen free.
   f. Pressure Plates: Stainless steel.
   g. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements.

D. SLEEVE-SEAL FITTINGS
1. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   a. Hold Rite.
   b. Metraflex Company (The).
   c. Pipeline Seal and Insulator, Inc.

2. Description: Manufactured plastic, sleeve-type, waterstop assembly made for imbedding in concrete slab or wall. Unit has plastic or rubber waterstop collar with center opening to match piping OD.

E. GROUT


2. Characteristics: Nonshrink; recommended for interior and exterior applications.

3. Design Mix: 5000-psi, 28-day compressive strength.


PART 3 - EXECUTION

3.01 ERECTION/INSTALLATION/APPLICATION

A. SLEEVE INSTALLATION

1. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls. Provide waterproof flashing through exterior above grade roof.

2. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1-inch annular clear space between piping and concrete slabs and walls.
   a. Sleeves are not required for core-drilled holes.

3. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
   a. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
   b. Cut sleeves to length for mounting flush with both surfaces.
      1) Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.
   c. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.

4. Install sleeves for pipes passing through interior partitions.
   a. Cut sleeves to length for mounting flush with both surfaces.
b. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.

c. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with applicable codes and standards requirements for joint sealants.

5. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

B. STACK-SLEEVE-FITTING INSTALLATION

1. Install stack-sleeve fittings in new slabs as slabs are constructed.
   a. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
   b. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with applicable codes and standard for flashing.
   c. Install section of soil pipe to extend sleeve to 2 inches above finished floor level.
   d. Extend sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
   e. Using grout, seal the space around outside of stack-sleeve fittings.

2. Fire-Barrier Penetrations: Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

C. SLEEVE-SEAL-SYSTEM INSTALLATION

1. Install sleeve-seal systems in sleeves in exterior concrete walls above and below grade and slabs-on-grade at service piping entries into building.

2. Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.


D. SLEEVE-SEAL-FITTING INSTALLATION

1. Install sleeve-seal fittings in new walls and slabs as they are constructed.

2. Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.

3. Secure nailing flanges to concrete forms.
4. Using grout, seal the space around outside of sleeve-seal fittings.

5. Fire-Barrier Penetrations: Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

E. SLEEVE AND SLEEVE-SEAL SCHEDULE

1. Use sleeves and sleeve seals for the following piping-penetration applications:
   a. Exterior Concrete Walls above Grade:
      1) Piping Smaller Than NPS 6: Cast-iron wall sleeves.
      2) Piping NPS 6 and Larger: Cast-iron wall sleeves.
   b. Exterior Concrete Walls below Grade:
      1) Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.
         a) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
      2) Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.
         a) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
   c. Concrete Slabs-on-Grade:
      1) Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.
         a) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
      2) Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.
         a) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.
   d. Concrete Slabs above Grade:
      1) Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves Stack-sleeve fittings.
      2) Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves Stack-sleeve fittings.
   e. Interior Partitions:
      1) Piping Smaller Than NPS 6: Galvanized-steel-pipe sleeves.
2) Piping NPS 6 and Larger: Galvanized-steel-sheet sleeves.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. Section Includes:
      1. Equipment labels
      2. Valve tags
      3. Warning signs and labels
      4. Pipe markers

1.02 REFERENCES
   A. This Section incorporates by reference the latest revisions of the following documents.
      1. American Society of Mechanical Engineers (ASME)
         a. ASME A13.1 Scheme for Identification of Piping Systems

1.03 ADMINISTRATIVE REQUIREMENTS
   A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
   B. Coordinate installation of identifying devices with locations of access panels and doors.
   C. Install identifying devices before installing acoustical ceilings and similar concealment.

1.04 SUBMITTALS
   A. Product Data: For each type of product indicated.
   B. Schedules: Submit valve schedule for each piping system, typewritten and reproduced on 8-1/2 by 11-inch bond paper for mounting. Tabulate valve number, piping system, system abbreviations as shown on tag, location of valve, and variations for identification. Mark valves that are intended for emergency shut-off and similar special uses with “flags” in the margin of schedule. In addition to mounted copies, furnish copies as required for maintenance manuals.
   C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2 by 11-inch bond paper. Tabulate equipment identification number and identify Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specifications Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.
   D. Samples: Submit samples of each color, lettering style, and other graphic representation required for each identification material or system.
1.05 QUALITY ASSURANCE

A. MATERIAL AND WORKMANSHIP

1. Materials and equipment required for the work shall be new and shall be furnished, delivered, erected, installed, connected, and finished in every detail; and shall be selected and arranged to fit properly into the building spaces. Where no specific kind or quality of material is given, an article as approved by the Resident Engineer shall be provided.

2. Equipment and materials shall be installed with the approval of the Resident Engineer in accordance with the recommendations of the manufacturer.

PART 2 - PRODUCTS

2.01 EQUIPMENT LABELS

A. Description

1. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 inches by 3/4 inch.

2. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

3. Label Content: Include equipment’s Contract Drawing designation or unique equipment number, Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specification Section number and title where equipment is specified.

B. Materials

1. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware if the label shall be mounted with fasteners.

C. Assembly or Fabrication

1. Fasteners: Stainless-steel rivets or stainless-steel self-tapping screws.

2. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.02 VALVE TAGS

A. Description

1. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.

B. Materials

1. Tag Material: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.

C. Assembly or Fabrication
1. Fasteners: Brass wire-link or beaded chain.

2.03 WARNING SIGNS AND LABELS

A. Description

1. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 inches by 3/4 inch.

2. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

3. Label Content: Include caution and warning information, plus emergency notification instructions.

B. Material

1. Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.
   a. Letter Color: White
   b. Background Color: Red

C. Performance

1. Maximum Temperature: Able to withstand temperatures up to 160 degrees F.

D. Assembly or Fabrication

1. Fasteners: Stainless-steel rivets or self-tapping screws.

2. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.04 PIPE MARKERS

A. Description

1. Preprinted, color-coded, with lettering indicating service, and showing flow direction.

2. Pipe Markers Contents: Include identification of piping service using same designations or abbreviations as used on Contract Drawings, pipe size, and an arrow indicating flow direction:
   a. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.
   b. Lettering Size: At least 1-1/2 inches high.

B. Materials

1. Pretensioned Pipe Markers: Precoiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.
2. Self-Adhesive Pipe Markers: Printed plastic with contact-type, permanent-adhesive backing.

C. Pipe Marker Color Schedule

1. Domestic Water Piping
   a. Background Color: Blue
   b. Letter Color: White

2. Sanitary Waste Piping
   a. Background Color: Brown
   b. Letter Color: White

3. Storm Drainage Piping
   a. Background Color: Black
   b. Letter Color: White

PART 3 - EXECUTION

A. PREPARATION

1. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

2. Coordinate installation with piping insulation and heat trace installation as required.

3.02 ERECTION / INSTALLATION / APPLICATION

A. EQUIPMENT LABEL INSTALLATION

1. Install or permanently fasten labels on each major item of mechanical equipment.

2. Locate equipment labels where accessible and visible.

B. VALVE TAG INSTALLATION

1. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.

   a. Valve Tag Size and Shape

      1) Cold Water: 1-1/2 inches round
      2) Hot Water: 1-1/2 inches round

C. PIPE MARKER INSTALLATION
1. Locate pipe marker where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
   a. Near each valve and control device.
   b. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
   c. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
   d. At access doors, manholes, and similar access points that permit view of concealed piping.
   e. Near major equipment items and other points of origination and termination.
   f. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.
   g. On piping above removable acoustical ceilings. Omit intermediately spaced labels.

D. STANDPIPE VALVE IDENTIFICATION SIGNS
1. Mount signs adjacent to valves with two 1/4-inch-diameter stainless steel fasteners and within 24 inches of valve and between 48 and 66 inches above floor height.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specification for the following soil and waste, sanitary drainage and vent piping inside the building:
   1. Pipe, tube, and fittings
   2. Special pipe fittings

1.02 REFERENCES

A. This section incorporates by reference the latest revisions of the following documents.
   1. ASTM International (ASTM)
      g. ASTM B306 Standard Specification for Copper Drainage Tube (DWV).
      h. ASTM B813 Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube.
      i. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings.
   2. American Society of Sanitary Engineering (ASSE)
      a. ASSE 1043 Performance Requirements for Cast Iron Sanitary Drainage Systems.
3. Manufacturers Standardization Society (MSS)
   a. MSS SP-69 Pipe Hangers and Supports – Selection and Applications.

1.03 ADMINISTRATIVE REQUIREMENTS
   A. Field quality-control inspection and test reports.

1.04 SUBMITTALS
   A. Shop Drawings.

1.05 QUALITY ASSURANCE
   A. Piping materials shall bear label, stamp, or other markings of an independent testing laboratory.

PART 2 - PRODUCTS

2.01 PIPING MATERIALS
   A. Hub-and-Spigot, Cast-Iron Pipe and Fittings: ASTM A74, Service class
   B. Hubless Cast-Iron Pipe and Fittings: ASTM A888 or CISPI 301
      1. Stack Fittings: ASME B16.45 or ASSE 1043, hubless, cast-iron aerator and deaerator drainage fittings.
      2. Shielded Couplings: ASTM C1277 or CISPI 301 assembly of metal shield or housing, corrosion-resistant fasteners, and rubber sleeve with integral, center pipe stop.
         a. Heavy-Duty, Shielded, Stainless-Steel Couplings: With stainless-steel shield, stainless-steel bands and tightening devices, and ASTM C564, rubber sleeve
   C. Steel Pipe: ASTM A53/A53M, Type E or S, Grade A or B, Schedule 40, galvanized. Include ends matching joining method.
      1. Drainage Fittings: ASME B16.12, galvanized, threaded, cast-iron drainage pattern.
      2. Pressure Fittings
         a. Steel Pipe Nipples: ASTM A733, made of ASTM A53/A53Mor
         b. ASTM A106, Schedule 40, galvanized, seamless steel pipe; include ends matching joining method.
         c. Malleable-Iron Unions: ASME B16.39; Class 150; hexagonal-stock body with ball-and-socket, metal-to-metal, bronze seating surface; and female threaded ends.
         e. Cast-Iron Flanges: ASME B16.1, Class 125
PART 3 - EXECUTION

3.01 APPLICATION

A. Special pipe fittings with pressure ratings at least equal to piping pressure ratings may be used in applications below, unless otherwise indicated.

B. Flanges and unions may be used on aboveground pressure piping, unless otherwise indicated.

C. Aboveground, soil, waste, and vent piping shall be any of the following: Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

1. Underground, soil, waste, and vent piping NPS 4 and smaller shall be any of the following:
   a. Service class, hub-and-spigot, cast-iron soil pipe and fittings; gaskets; and compression joints.
   b. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

D. Underground, soil and waste piping NPS 5 and larger shall be any of the following:

1. Service class, cast-iron soil pipe and fittings; gaskets; and compression joints.

2. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

3.02 INSTALLATION

A. Piping Installation

1. Install cleanouts at grade and extend to where building sanitary drains connect to building sanitary sewers.

2. Install cast-iron sleeve with water stop and mechanical sleeve seal at each service pipe penetration through foundation wall. Select number of interlocking rubber links required to make installation watertight. Sleeves and mechanical sleeve seals, and wall sleeves shall apply. Install cast-iron soil piping according to CISPI’s “Cast Iron Soil Pipe and Fittings Handbook,” Chapter IV, “Installation of Cast Iron Soil Pipe and Fittings.”

3. Make changes in direction for soil and waste drainage and vent piping using appropriate branches, bends, and long-sweep bends. Sanitary tees and short-sweep 1/4 bends may be used on vertical stacks if change in direction of flow is from horizontal to vertical. Use long-turn, double Y-branch and 1/8-bend fittings if two fixtures are installed back to back or side by side with common drain pipe. Straight tees, elbows, and crosses may be used on vent lines. Do not change direction of flow more than 90 degrees. Use proper size of standard increasers.
and reducers if pipes of different sizes are connected. Reducing size of drainage piping in direction of flow is prohibited.

4. Lay buried building drainage piping beginning at low point of each system. Install true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets according to manufacturer’s written instructions for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.

5. Install soil and waste drainage and vent piping at the following minimum slopes, unless otherwise indicated:

a. Building Sanitary Drain: 2 percent downward in direction of flow for piping NPS 4 and smaller; for pipe larger than NPS 4 1 percent downward in direction of flow for piping is allowed.

b. Horizontal Sanitary Drainage Piping: 2 percent downward in direction of flow.

c. Vent piping: 2 percent down toward vertical fixture vent or toward vent stack unless indicated otherwise.

6. Sleeves are not required for cast iron soil piping passing through concrete slabs-on-grade if slab is without membrane waterproofing.

7. Do not enclose, cover, or put piping into operation until it is inspected and approved by authorities having jurisdiction.

B. Joint Construction


2. Gasketed Joints: Make with rubber gasket matching class of pipe and fittings.

3. Hubless Joints: Make with rubber gasket and sleeve or clamp.

4. Soldered Joints: Use ASTM B813, water-flushable, lead-free flux; ASTM B32, lead-free-alloy solder; and ASTM B828 procedure, unless otherwise indicated.

C. Valve Installation

1. Shutoff Valves: Install shutoff valve on each sewage pump discharge.

a. Use gate or full-port ball valve for piping NPS 2 and smaller.

b. Use gate valve for piping NPS 2-1/2 and larger.

2. Check Valves: Install swing check valve, downstream from shutoff valve, on each sewage pump discharge.


a. Horizontal Piping: Horizontal backwater valves. Use normally closed type, unless otherwise indicated.

b. Floor Drains: Drain outlet backwater valves, unless drain has integral backwater valve.
c. Install backwater valves in accessible locations.

D. **Hanger and Support Installation**

1. **Pipe Hangers**
   
a. Vertical Piping MSS Type 8 or Type 42, clamps

b. Individual, Straight, Horizontal Piping Runs: According to the following
   
   1) 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers
   2) Longer than 100 Feet: MSS Type 43, adjustable roller hangers
   3) Longer than 100 Feet, if indicated: MSS Type 49, spring cushion rolls

2. Install supports as required.

3. Support vertical piping and tubing at base and at each floor.

4. Rod diameter may be reduced one size for double-rod hangers, with 3/8-inch minimum rods.

5. Install hangers for cast-iron soil piping, steel piping and copper tubing with the following maximum horizontal spacing and minimum rod diameters as specified in UPC.

   a. Install supports for vertical cast-iron soil piping, steel piping and copper piping as specified in UPC.

6. Support piping and tubing not listed above according to MSS SP-69 and manufacturer’s written instructions and meet the requirements of UPC.

E. **Connections**

1. Connect soil and waste piping to exterior sanitary sewerage piping. Use transition fitting to join dissimilar piping materials.

2. Connect drainage and vent piping to the following:
   
a. Plumbing Fixtures: Connect drainage piping in sizes indicated, but not smaller than required by plumbing code.

b. Equipment: Connect atmospheric vent piping in sizes indicated, but not smaller than required by authorities having jurisdiction.

c. Plumbing Specialties: Connect drainage and vent piping in sizes indicated, but not smaller than required by plumbing code and specification section of Sanitary Waste Piping Specialties.

d. Equipment: Connect drainage piping as indicated. Provide shutoff valve, if indicated, and union for each connection. Use flanges instead of unions for connections NPS 2-1/2 and larger.
3.03 FIELD QUALITY INSPECTION

A. During installation, notify Resident Engineer at least 24 hours before inspection shall be performed. Perform tests specified below in presence of Resident Engineer and the Authority having Jurisdiction (AHJ).

1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in and before setting fixtures.
2. Final Inspection: Arrange for final inspection by Resident Engineer and the AHJ to observe tests specified below and to ensure compliance with requirements.
3. Installation Verification shall apply prior to and before commissioning. Refer to commissioning of plumbing in other sections for verification documentation.

B. Reinspection: If Resident Engineer and the AHJ find that piping will not pass test or inspection, make required corrections and arrange for reinspection.

C. Reports: Prepare inspection reports and have them signed by Resident Engineer and the AHJ.

D. Test sanitary drainage and vent piping according to manufacturers' procedures of Resident Engineer and the AHJ.

1. Test installed drainage lines and equipment according to Section 22 08 00, Commissioning of Plumbing. Provide and dispose of water required for testing.
2. Prepare reports for tests and required corrective action.

E. Components and installation shall be capable of withstanding the following minimum working pressure, unless otherwise indicated:


3.04 CLEANING

A. Clean interior of piping. Remove dirt and debris as work progresses.

B. Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.

C. Place plugs in ends of uncompleted piping at end of day and when work stops.

3.05 COMMISSIONING

A. Engage a factory-authorized service representative to train Sound Transit’s maintenance personnel to adjust, operate, and maintain Sanitary Waste and Vent Piping systems and equipment. See Section 22 08 00, Commissioning of Plumbing for commissioning requirements pertaining to the work of this section.

3.06 CLOSEOUT ACTIVITIES

A. Engage a factory-authorized service representative to train Sound Transit’s maintenance personnel to adjust, operate, and maintain Sanitary Waste and Vent Piping systems and equipment. See commissioning of plumbing in other sections for commissioning requirements pertaining to the work of this Section.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Sleeves.
   2. Stack-sleeve fittings.
   3. Sleeve-seal systems.
   4. Sleeve-seal fittings.
   5. Grout.

1.02 REFERENCES

A. ASTM A53
B. ASTM E84/E814
C. ASME B36.10
D. UL (FRD) – Fire Resistance

1.03 SUBMITTALS

A. Product Data: For each type of product indicated.

PART 2 - PRODUCTS

2.01 SLEEVES

A. Cast-Iron Wall Pipes: Cast or fabricated of cast or ductile iron and equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop unless otherwise indicated.

B. Galvanized-Steel Wall Pipes: ASTM A 53/A 53M, Schedule 40, with plain ends and welded steel collar; zinc coated.

C. Galvanized-Steel-Pipe Sleeves: ASTM A 53/A 53M, Type E, Grade B, Schedule 40, zinc coated, with plain ends.

D. Galvanized-Steel-Sheet Sleeves: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

2.02 STACK-SLEEVE FITTINGS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. Description: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring, bolts, and nuts for membrane flashing.
   1. Underdeck Clamp: Clamping ring with setscrews.

2.03 SLEEVE-SEAL SYSTEMS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. Advance Products & Systems, Inc.
   2. CALPICO, Inc.
   3. Metraflex Company (The).
   4. Link-Seal
   5. Pipeline Seal and Insulator, Inc.
   6. Proco Products, Inc.

B. Description: Modular sealing-element unit, designed for field assembly, for filling annular space between piping and sleeve.
   1. An assembly consisting of a stainless steel frame, a compression mechanism, and insert modules for pipe, duct and tubing.
   2. Comply with F- and T-ratings as required by local codes, code official, and as tested in accordance with ASTM E814 or UL1479.
   3. Sealing Elements: EPDM-rubber interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
   4. Designs should be water and gas tight to 14.5 psi.
   5. Seals shall be asbestos free, lead free, halogen free
   6. Pressure Plates: Reinforced Nylon Polymer or Stainless steel.
   7. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements.

2.04 SLEEVE-SEAL FITTINGS

A. Manufacturers: Subject to compliance with requirements, available manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   1. HoldRite
   2. The Metraflex Company.
   3. Pipeline Seal and Insulator, Inc.

B. Description: Manufactured plastic, sleeve-type, waterstop assembly made for imbedding in concrete slab or wall. Unit has plastic or rubber waterstop collar with center opening to match piping OD.
2.05 GROUT
B. Characteristics: Nonshrink; recommended for interior and exterior applications.
C. Design Mix: 5000-psi, 28-day compressive strength.
D. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.01 SLEEVE INSTALLATION
A. Install sleeves for piping passing through penetrations in floors, partitions, roofs, and walls. Provide waterproof flashing through exterior above grade roof.
B. For sleeves that will have sleeve-seal system installed, select sleeves of size large enough to provide 1-inch annular clear space between piping and concrete slabs and walls.
   1. Sleeves are not required for core-drilled holes.
C. Install sleeves in concrete floors, concrete roof slabs, and concrete walls as new slabs and walls are constructed.
   1. Permanent sleeves are not required for holes in slabs formed by molded-PE or -PP sleeves.
   2. Cut sleeves to length for mounting flush with both surfaces.
      a. Exception: Extend sleeves installed in floors of mechanical equipment areas or other wet areas 2 inches above finished floor level.
   3. Using grout, seal the space outside of sleeves in slabs and walls without sleeve-seal system.
D. Install sleeves for pipes passing through interior partitions.
   1. Cut sleeves to length for mounting flush with both surfaces.
   2. Install sleeves that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
   3. Seal annular space between sleeve and piping or piping insulation; use joint sealants appropriate for size, depth, and location of joint. Comply with applicable codes and standards requirements for sealants.
E. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for fire stopping.

3.02 STACK-SLEEVE-FITTING INSTALLATION
A. Install stack-sleeve fittings in new slabs as slabs are constructed.
   1. Install fittings that are large enough to provide 1/4-inch annular clear space between sleeve and pipe or pipe insulation.
2. Secure flashing between clamping flanges for pipes penetrating floors with membrane waterproofing. Comply with requirements for flashing as specified elsewhere in the Contract Documents—applicable codes and standard for flashing.

3. Install section of cast-iron soil pipe to extend sleeve to 2 inches above finished floor level.

4. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.

5. Using grout, seal the space around outside of stack-sleeve fittings. Comply with applicable codes and standards requirements for joint sealants.

**B. Fire-Barrier Penetrations:** Maintain indicated fire rating of floors at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

### 3.03 SLEEVE-SEAL-SYSTEM INSTALLATION

**A.** Install sleeve-seal systems in sleeves in exterior concrete walls and slabs-on-grade at service piping entries into building.

**B.** Select type, size, and number of sealing elements required for piping material and size and for sleeve ID or hole size. Position piping in center of sleeve. Center piping in penetration, assemble sleeve-seal system components, and install in annular space between piping and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make a watertight seal.

**C.** Fire-Barrier Penetrations: Maintain indicated fire rating of wall, floor at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with requirements for firestopping as specified in this specification section.

### 3.04 SLEEVE-SEAL-FITTING INSTALLATION

**A.** Install sleeve-seal fittings in new walls and slabs as they are constructed.

**B.** Assemble fitting components of length to be flush with both surfaces of concrete slabs and walls. Position waterstop flange to be centered in concrete slab or wall.

**C.** Secure nailing flanges to concrete forms.

**D.** Using grout, seal the space around outside of sleeve-seal fittings.

**E.** Fire-Barrier Penetrations: Maintain indicated fire rating of wall, floor at pipe penetrations. Seal pipe penetrations with firestop materials. Comply with applicable codes and standards requirements for firestopping.

### 3.05 SLEEVE AND SLEEVE-SEAL SCHEDULE

**A.** Use sleeves and sleeve seals for the following piping-penetration applications:

1. **Exterior Concrete Walls above Grade:**
   
a. Piping Smaller Than NPS 6: Cast-iron wall sleeves.

b. Piping NPS 6 and Larger: Cast-iron wall sleeves.

2. **Exterior Concrete Walls below Grade:**
a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.

1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

b. Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.

1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

3. Concrete Slabs-on-Grade:

a. Piping Smaller Than NPS 6: Cast-iron wall sleeves with sleeve-seal system.

1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

b. Piping NPS 6 and Larger: Cast-iron wall sleeves with sleeve-seal system.

1) Select sleeve size to allow for 1-inch annular clear space between piping and sleeve for installing sleeve-seal system.

4. Concrete Slabs above Grade:


b. Piping NPS 6 and Larger: Galvanized-steel-pipe sleeves Stack-sleeve fittings.

5. Interior Partitions:


END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. Section Includes:
   1. Equipment labels
   2. Warning signs and labels
   3. Pipe labels
   4. Duct labels
   5. Stencils
   6. Valve tags
   7. Valve Labels
   8. Warning tags

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. ASME A13.1 Scheme for Identification of Piping Systems

1.03 ADMINISTRATIVE REQUIREMENTS
A. COORDINATION
   1. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
   2. Coordinate installation of identifying devices with locations of access panels and doors.
   3. Install identifying devices before installing acoustical ceilings and similar concealment.

1.04 SUBMITTALS
A. Submittals
   1. Product Data: For each type of product indicated.
   2. Samples: For color, letter style, and graphic representation required for each identification material and device.
3. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.

4. Valve Schedules with numbering scheme: For each piping system to include in maintenance manuals.

PART 2 - PRODUCTS

2.01 EQUIPMENT LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware if the label is to be mounted with fasteners.

B. Letter Color: Black

C. Background Color: White

D. Maximum Temperature: Able to withstand temperatures up to 160 degrees Fahrenheit.

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.


H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

I. Label Content: Include equipment’s Contract Drawing designation or unique equipment number, Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specification Section number and title where equipment is specified.

2.02 WARNING SIGNS AND LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware if the label is to be mounted with fasteners.


C. Background Color: Red.

D. Maximum Temperature: Able to withstand temperatures up to 160 degrees Fahrenheit.

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering 2/3 to 3/4 the size of principal lettering.

H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
I. Label Content: Include caution and warning information, plus emergency notification instructions.

2.03 PIPE LABELS
A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.
B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to partially cover circumference of pipe and to attach to pipe without fasteners or adhesive.
C. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.
D. Pipe Label Schedule Schedule:
   1. Hydronic Piping:
      a. Background Color: Green
   2. Refrigerant Piping:
      a. Background Color: Black.
E. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.
   1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions or as separate unit on each pipe label to indicate flow direction.
   2. Lettering Size: At least 1-1/2 inches high.

2.04 DUCT LABELS
A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware if the label is to be mounted with fasteners.
C. Background Color in the following color codes:
   1. Blue: Supply air and mixed-air ducts.
   2. Green: For exhaust, outside-, relief-, and return ducts.
   3. ASME A13.1 Colors and Designs: For hazardous material exhaust.
D. Maximum Temperature: Able to withstand temperatures up to 160 degrees Fahrenheit.
E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering 2/3 to 3/4 the size of principal lettering.


H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

I. Duct Label Contents: Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.
   1. Flow-Direction Arrows: Integral with duct system service lettering to accommodate both directions or as separate unit on each duct label to indicate flow direction.
   2. Lettering Size: At least 1-1/2 inches high.

2.05 STENCILS

A. Stencils: Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches for ducts; and minimum letter height of 3/4 inch for access panel and door labels, equipment labels, and similar operational instructions.
   2. Stencil Paint: Exterior, gloss, alkyd enamel black unless otherwise indicated. Paint may be in pressurized spray-can form.
   3. Identification Paint: Exterior, alkyd enamel in colors according to ASME A13.1 unless otherwise indicated.

2.06 VALVE TAGS

A. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.
   1. Tag Material: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
   2. Fasteners: Brass wire-link or beaded chain; or S-hook.

B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:
   1. Valve-Tag Size and Shape:
   2. Valve-Tag Color:
      a. Hydronic and Refrigerant: Natural.
   3. Letter Color:
      a. Hydronic and Refrigerant: Black.

C. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of
valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

1. Valve-tag schedule shall be included in operation and maintenance data and hard copy on site, final location to be determined by ST.

2.07 VALVE LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware if the label to be mounted with fasteners.

B. Valve Label Schedule Valve Label Application Schedule: Valves label according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

1. Valve Label Size and Shape:
   a. Hydronic and Refrigerant: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
   b. Minimum Letter Size: 1/4 inch for name of valves if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

C. Maximum Temperature: Able to withstand temperatures up to 160 degrees Fahrenheit.

D. Fasteners: Stainless-steel self-tapping screws.

E. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate

2.08 WARNING TAGS

A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.

1. Size: Approximately 4 by 7 inches.
2. Fasteners: Brass grommet and wire.
3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."

PART 3 - EXECUTION

3.01 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.02 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.
B. Locate equipment labels where accessible and visible.

3.03 PIPE LABEL INSTALLATION

A. Piping Color-Coding: Painting of piping shall be per the requirements of high-performance coatings as specified elsewhere in the Contract Documents.

B. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer’s option. Install stenciled pipe labels, complying with ASME A13.1, on each piping system.

1. Identification Paint: Use for contrasting background.


C. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.

2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.

3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.

4. At access doors, manholes, and similar access points that permit view of concealed piping.

5. Near major equipment items and other points of origination and termination.

6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 in areas of congested piping and equipment.


3.04 DUCT LABEL INSTALLATION

A. Install plastic-laminated self-adhesive duct labels with permanent adhesive on air ducts.

B. Stenciled Duct Label Option: Larger sized stenciled labels, showing service and flow direction may be provided instead of plastic-laminated duct labels, at Installer’s option, if lettering larger than 1 inch high is needed for proper identification because of distance from normal location of required identification.

C. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system. Reduced intervals to 25 feet in areas of congested piping and equipment.

3.05 VALVE-TAG AND VALVE LABEL INSTALLATION

A. Valve-Tag Installation:

1. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.
B. Valve Label Installation

   1. As an option, valve label in place of valve tags can be installed on wall or column not more than 6 inches behind the valve. Install valve label for valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves, and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List valve labels in a valve schedule.

C. Warning-Tag Installation

   1. Write required message on, and attach warning tags to, equipment and other items where required.

END OF SECTION
SECTION 26 05 00
COMMON WORK RESULTS FOR ELECTRICAL

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for general electrical requirements that apply to other specification sections.

1.02 REFERENCES

A. This Section incorporates by reference the latest Authority Having Jurisdiction (AHJ) approved revisions of the following documents.

1. Institute of Electrical and Electronics Engineers (IEEE)
   b. IEEE 141 – Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems
   c. IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
   d. IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis
   e. IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings
   g. IEEE 1584 -Guide for Performing Arc-Flash Hazard Calculations

2. National Electrical Contractors Association (NECA)
   a. NECA NEIS 1 Standard Practice of Good Workmanship in Electrical Construction

3. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code
   b. NFPA 70E Standard for Electrical Safety in the Workplace
   c. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

   a. 19.27 RCW Washington State Building Code
   b. 19.28 RCW Electricians and Electrical Installations
   a. 51-50 WAC State Building Code Adoption and Amendments of the International Building Code
   b. 296-45 WAC Safety Standards for Electrical Workers
   c. 296-46B WAC Electrical Safety Standards, Administration, and Installation

6. Local City and AHJ Electrical Code

7. Local City and AHJ Building Code

1.03 SUBMITTALS

A. List of Materials: Submit a list of materials and equipment proposed for use. Give name of manufacturer, brand name, and catalog number of each item. Submit the list complete at one time, with items arranged and identified in numerical sequence by Specifications Section and Article numbers.

B. Compliance with Applicable Standards:
   1. Where equipment or materials are specified to conform to the standards of organizations such as ANSI, ASTM, IEEE, and NEMA, submit evidence of such conformance for review and record purposes.
   2. The label or listing of the specified agency will be acceptable evidence.
   3. Instead of the label or listing, the Contractor may submit a written certificate from an approved, nationally recognized testing organization, adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the specified standard.

C. Factory Test and Inspection Certification:
   1. Where factory tests and inspections for materials and equipment specified in referenced documents are waived, submit certified copies of reports for tests performed on previously manufactured identical materials or equipment within the previous 12 months for review and approval.
   2. Accompany test reports by signed statements from the manufacturer certifying that the previously tested material or equipment is physically, mechanically, and electrically identical to that proposed for the Contract. Include wiring and control diagrams.

D. Shop Drawings: Submit shop drawings showing equipment layouts and fabricated work being provided under these Specifications. Submit such drawings before rough-in work, fabrication, and within ample time to prevent delays in the Work. Include electrical diagrams for equipment and equipment installation.

E. Field Test Reports: Submit certified field test reports of field tests, verifying compliance of equipment and systems with Specification requirements.

F. Operation and Maintenance Manuals: Submit operation and maintenance instructions and data for equipment provided under this Division, in accordance with the requirements
as stated elsewhere in the Specifications and Contract Documents. Include recommended maintenance materials and spare parts list for installed equipment.

G. Sound Transit Cover Fasteners Keys: Submit ten key bits as described in Article 2.01.B.3 herein.

1.04 QUALITY ASSURANCE

A. Qualifications: Ensure workers performing work meet the qualification and licensing requirements of Chapter 19.28 RCW.

B. Perform work in compliance with the following industry standards and regulations if applicable.

1. National Fire Protection Association
   a. NFPA 70 National Electrical Code
   b. NFPA 70E Standard for Electrical Safety in the Workplace
   c. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

2. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   a. IEEE 141 – Recommended Practice for Electric Power Distribution and Coordination of Industrial and Commercial Power Systems
   b. IEEE 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
   c. IEEE 399 – Recommended Practice for Industrial and Commercial Power System Analysis
   d. IEEE 241 – Recommended Practice for Electric Power Systems in Commercial Buildings
   f. IEEE 1584 -Guide for Performing Arc-Flash Hazard Calculations
   g. IEEE C2 National Electrical Safety Code

3. NECA NEIS 1, Standard Practice of Good Workmanship in Electrical Construction

4. State of Washington Business Regulations and Administrative Codes

5. Relevant amendments to Washington State regulations and codes adopted by local jurisdictions.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General

1. Furnish materials and equipment of design, sizes, and ratings as indicated-suitable for the intended purpose.
2. Furnish materials and equipment acceptable to the authority having jurisdiction bearing label or classification listing of a nationally-recognized testing laboratory where product labeling or listing is available.

3. Methods of fabrication, assembly, and installation shall comply with specified Standards.

4. Provide products that are free from defects, which may impair performance, durability, or appearance.

B. Switches

1. Provide ac, tumbler-type toggle switches conforming to minimum requirements of FS W-S-896, heavy-duty general use type.

2. Provide switches that operate in any position and are fully enclosed with entire body and cover of molded phenolic, urea, or melamine. Do not use fiber, paper, or similar flammable insulating material for body or cover.

3. Equip switches with metal mounting yoke with plaster ears, insulated from the mechanism and fastened to the switch body by bolts, screws, or other substantial means.

4. Provide the section of the yoke normally intended to bear on the surface outside the box with a minimum overall dimension of 3/4 inch, measured at right angles to the longitudinal axis of the yoke.

5. Use switch contacts of silver or silver alloy.

6. Use switches that are back or side wired with terminals of screw type or combination screw-clamp type.

7. Use terminal screws No. 8 or larger, captive or terminal type.

8. For use on lighting circuits, provide switches that are fully-rated for 20 A at 120 V or 277 V. Switches shall be gray color or as selected by Resident Engineer.

9. For control of resistive loads, switches may be snap-type as specified herein, of the proper rating up to 30 A at 120 - 277 V.

10. Provide 120 - 277 Vac snap switches capable of withstanding tests as outlined in FS W-S-896. If requested by Resident Engineer, submit evidence that the types of switches proposed have satisfactorily withstood these tests.

C. Receptacles

1. Receptacle Standards: Ensure connector and outlet receptacles conform to FS W-C-596, heavy-duty general use type and NEMA WD6.

2. Convenience Receptacles.

   a. Provide receptacles with fire-resistant, nonabsorptive, hot-molded phenolic composition bodies and bases and with metal plaster ears integral with supporting member. Color shall be as described in the Contract Documents.

   b. Use receptacles that are 20R configuration, single- or duplex-type as indicated. Use receptacles that are back- and side-wired with screw or combination screw-clamp terminals.
c. For contacts of the receptacles, including the grounding contact, use double-grip bronze type with spring steel backup clips so that both sides of each male prong of the plug will be in firm contact.

3. Locking-Blade Receptacles: NEMA WD 6, configuration subject to approval.

4. GFCI Receptacles.
   a. For ground fault circuit interrupter (GFCI) duplex receptacles use 120 V, 60 Hz, 20 A with built-in test and reset buttons and ground fault trip indicator.
   b. Ensure they interrupt the circuit within 1/30 second on a 5 mA earth leakage current.
   c. Receptacles shall also trip if the receptacle is incorrectly wired or if the ground-fault sensing/tripping unit fails.
   d. Provide devices designed for end-of-run installation or with provisions for feeding through to protect other outlets on the circuit. Circuit capacity for feeding through shall be 20 A.
   e. Provide receptacles with clamp-type terminals, mounting screws, and instructions.

5. Wallplates.
   a. Provide multi-gang plates where required. Segmented wallplates are not acceptable.
   b. Finished Area Device Covers: Brushed stainless steel, 0.040-inch thickness.
   c. Utility Area Device Covers: Raised, galvanized steel
   d. Exterior and Wet Location Cover:
      1) NEC-compliant "while-in-use" cover
      2) Heavy-duty, die-cast aluminum, powder coated
      3) Listed for wet locations, rated NEMA 250 Type 3R, with neoprene gasket
      4) Padlockable
      5) Depth: Minimum 3-1/4 inches
   e. Damp Location Cover: Die-cast, copper-free aluminum listed for wet locations with self-closing spring door and rubber gasket.

PART 3 - EXECUTION

3.01 INSTALLATION
   A. Install products in accordance with product listings, manufacturer’s recommendations, relevant codes and regulations, and standard industry practice for electrical installations.
B. Install electrical materials, equipment, appurtenances, and accessories in locations as indicated, in accordance with NECA NEIS 1, to provide a complete and operable system. Do not weld electrical materials for attachment or support.

C. Provide anchor bolts and anchorage items as required, and field check to ensure proper alignment and location. Provide templates, layout drawings, and supervision at the jobsite to ensure correct placing of anchorage items in concrete. Check embedded items for correctness of location and detail before concrete is placed.

D. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles as required to set and connect the work rigidly.

E. Conform to the seismic restraint requirements of the AHJ-approved Building Code and Washington State Building Code.

F. Ensure electrical equipment installed under these Specifications conforms to the AHJ-approved Building Code and the International Building Code Section 1621, Architectural, Mechanical, and Electrical Component Seismic Design Requirements.

G. Control erection tolerance requirements so as to not impair the strength, safety, serviceability, or appearance of the installations.

H. Install switches, receptacles, special purpose outlets, and cover plates complete in accordance with NECA NEIS 1, the National Electrical Code, and local electrical codes.

I. Seal equipment enclosures against dust, whenever dusty conditions are present inside the rooms or outside, during the construction period.

J. Contractor shall provide computer-based power system studies, short circuit calculations, overcurrent protective device coordination, Arc Flash Hazard Analysis Report per the requirements in the current version of NFPA 70E, and a transient switch study with calculations if there is an Sound Transit owned medium-voltage transformer protected by a vacuum circuit breaker.

1. The arc flash hazard analysis shall be performed according to the IEEE Standard 1584, the IEEE Guide for Performing Arc Flash Calculations. The scope of the study shall include the complete electrical system using the final installed equipment configuration.

2. Determine the arc-flash hazard distance and the incident energy to which personnel could be exposed during work on or near electrical equipment per NFPA 70E.

3. Provide and install the arc flash labels based on the study.

4. Arc flash study to comply with NEC.

3.02 WALLPLATE TYPE REQUIREMENTS

A. Public areas: Provide Finished Area device covers.

B. Non-Public areas: Provide Utility Area wallplates in ancillary spaces, mechanical rooms, fan rooms, electrical closets, electrical rooms, traction power substations, and unfinished areas.

C. Special purpose outlets: Provide Finished Area device covers of a design for the particular application.

D. Exterior and wet locations: Provide specified exterior and wet location while-in-use covers.
E. Damp locations: Provide specified damp location covers.

3.03 SEISMIC DESIGN AND BRACING

A. Equipment provided shall meet seismic requirements specified in the AHJ-approved building code. Provide suitable bracing and anchorage and submit calculations performed and sealed by a structural engineer registered in Washington.

3.04 CONSTRUCTION

A. Wiring.

1. Provide wiring systems complete as indicated and required for proper service. Provide ample slack wire for motor loops, service connections, and extensions. In outlet or junction boxes provided for installation of equipment by others, insulate and protect ends of wires and cables and install blank covers.

B. Wiring Devices and Wall Plates.

1. Locate wiring devices at heights in accordance with NECA 1, except as otherwise indicated.

2. For exterior and damp locations including passenger stations, mount receptacles in watertight cast metal outlet boxes with threaded hubs or bosses.

3. Provide water-tight, locking-type male plugs protected by a ground-fault circuit interrupter for equipment subject to spray or hose cleaning.

4. Provide GFCI duplex receptacles where indicated.

5. Provide wallplates for each switch, receptacle, and special purpose outlet.

C. Interface With Other Work.

1. Coordinate the Work of this Section with the Work of others, as required to provide a complete and operable electrical installation.

2. Coordinate electrical services and Work with the serving utility company and Sound Transit, as applicable.

3. Coordinate with Work completed or in progress or to be performed under other Sections of these Specifications or by other contractors.

   a. Make indicated connections to previously completed work.

   b. Where future connections to or extensions of the work are indicated, provide safe and convenient provisions for such future connections and extensions.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for providing nameplates, wire and cable markers, conduit tags, and conduit color coding.

1.02 SUBMITTALS
A. Submit manufacturer’s product data for nameplate mounting hardware.
B. Submit schedule for nameplates including list of wording, symbols, letter size, color coding, tag number, location, and function.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Nameplates:
   1. Engraved three-layer melamine laminated plastic, not less than 3/32 inch thick.
   2. Color: Black letters on a white background unless otherwise noted.
   3. Emergency equipment cabinets: Nameplates shall have white letters on an orange background in accordance with NFPA 70 code requirements.
B. Wire and Cable Markers:
   2. Cable Tags: Non-fading, plastic, printed cable tag with holes for attachment to cable with nylon cable ties.
C. Conduit Tags:
   1. Size: See 3.02.
   2. Type: Designed for permanent identification.
D. Mounting Screws: Stainless steel machine screws or rivets
E. Mounting Adhesive: Permanent
PART 3 - EXECUTION

3.01 INSTALLATION

A. Nameplates and Identification Labels.
   1. Degrease and clean surfaces to receive nameplates and identification labels.
   2. Install nameplates parallel to equipment and conduit lines.
   3. Secure nameplates to equipment fronts using screws or rivets. Secure nameplate to inside face of recessed panelboard or cabinet doors in finished locations.

B. Cable Tags: Affix securely to cables and conductor bundles using compatible nylon cable ties.

C. Conduit Tags: Comply with manufacturer’s recommended installation procedures for a permanent installation.

D. Wire and Cable Markers.
   1. Heat-shrink wire and cable markers after final installation and testing.

3.02 CONSTRUCTION

A. Identification Schedule
   1. Conductors:
      a. Provide sleeve wire markers printed and installed in accordance with manufacturer’s recommendations to identify each single and multiple-conductor wire and cable in panelboards, gutters, pull boxes, manholes, and at load connections.
      b. In gutters, pull boxes, and manholes, if cables are not spliced, a cable tag shall be used. Attach tag securely to cable with nylon cable tie at location accessible and visible by personnel.
      c. Identify cable destination and number of conductors in cable as described in Contract Drawings.
         1) Power and Lighting Circuits: Identify with branch circuit or feeder number.
         2) Control Wiring: Identify with control wire number as indicated on the Contract Drawings or fabricator’s shop drawings.

   2. Conduit and MC Cable Identification:
      a. Where accessible in canopy columns and light poles, provide tag identifying system type and identifier listed on conduit and conductor schedule. Attach tag securely with nylon cable tie.
      b. Provide tags on conduits at conduit termination and access points.
      c. For conduits with assigned raceway numbers, provide conduit tag matching conduit identification on Contract Documents. For multiple,
parallel raceways with one raceway identifier, assign supplementary letter designations for each raceway group.

d. For conduits without assigned raceway numbers, provide generic conduit tag describing system (communications, signals, power lighting, etc.) plus identification of associated termination points.

e. Font Size

1) 3/4 inch tags: Minimum 36-point
2) 1 inch tags: Minimum 48-point
3) If exposed conduit length is not sufficient to accommodate these font sizes, reduce font to the maximum size possible, rotate tag at 90-degrees, or apply tag to equipment or box nearest conduit termination.

3. Provide nameplates of minimum letter height as scheduled below unless otherwise noted.

a. Each disconnecting means shall be marked with an identification plate in letters at least 1/2 inch high.

b. Panelboards, Switchboards, and Lighting Controllers: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating and source.

c. Disconnect Switches: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating, source, and load served.

d. Individual Circuit Breakers in Panelboards: 1/4 inch; identify circuit with load served. For lighting, include the specific zone in the description if applicable on the schedule.

e. Motor Starters: 1/4 inch; identify circuit.


g. Transformers: 3/8 inch; identify equipment designation. 1/4 inch; identify primary and secondary voltages, primary source, and secondary load and location.

h. Devices: 1/4 inch; identify device.

1) Dimmers
2) Control devices
3) Pushbutton stations

4. Emergency Systems: For all boxes and enclosures larger than 6 inches by 6 inches (including transfer switches, central lighting inverters, and power panels) for emergency circuits, provide a permanent identification plate that is orange in color with white lettering. All other device and junction boxes for emergency systems and circuits shall be orange in color, both inside and outside.

5. Smoke Control Systems: For all boxes and enclosures larger than 6 inches by 6 inches (including transfer switches, central lighting inverters, and power panels)
for smoke control power and control circuits, provide a permanent identification plate that is orange in color with a yellow diagonal stripe. All other device and junction boxes for smoke control systems and circuits shall be orange in color, both inside and outside. Cover plates shall be orange in color with a yellow diagonal stripe.

6. Stair pressurization systems: For all boxes and enclosure larger than 6 inches by 6 inches (including transfer switches, central lighting inverters, and power panels) for stair pressurization power and control circuits, provide a permanent identification plate that is orange in color with a gray diagonal stripe. All other device and junction boxes for stair pressurization systems and circuits shall be orange in color, both inside and outside. Cover plates shall be orange in color with a gray diagonal stripe.

7. Non-Emergency Systems: For all boxes and enclosures larger than 6 inches by 6 inches for non-emergency circuits, provide a permanent identification plate that is black in color with white lettering.

8. Fire Alarm Systems: For all boxes and enclosures larger than 6 inches by 6 inches for fire alarm circuits, provide a permanent identification plate that is red in color with white lettering. All other devices and junction boxes for fire alarm systems and circuits shall be red in color, both inside and outside.

9. Concrete Paver Covering Electrical Handhole: Install ferrule inserts in four corners of pavers to identify location of handhole beneath paver where indicated on Drawings.

B. Conduit Color Coding

1. Low-voltage and Medium voltage Distribution Systems: Unpainted or black

2. Fire Alarm System: Junction boxes / conduit bodies shall be substantially red in color both inside and out. Conduit and couplings shall be substantially red in color.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for testing trackwork to determine the track-to-earth resistance values and rail-to-rail resistance values of the running rails.

B. The procedures presented in this Section are general guidelines for the measurement of track-to-earth resistance and rail-to-rail resistance as construction progresses. These procedures shall be modified to suit actual field conditions and the electrical networks established by the trackwork that results from continuing construction.

C. The Contractor shall perform the testing set forth in this Section. It is the Contractor’s responsibility to construct trackwork that meets the established criteria. Repair or replace any trackwork found deficient at the Contractor's expense with no additional costs to Sound Transit.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. ASTM G165 Standard Practice for Determining Rail-to-Earth Resistance

1.03 SUBMITTALS

A. Testing Agency Qualifications

Testing firm qualifications, including resumes and certifications for all testing personnel and supervisors.

B. Testing Plan

The test plan including the schedule for work, procedures, testing forms, test methods, acceptance criteria, and equipment to be used.

C. Test Reports

All trackwork isolation testing data, records, calculations, results, and reports. Test submittals shall include sufficient information so that the results are identifiable and traceable to installed components or locations.

1.04 QUALITY ASSURANCE

A. The Contractor shall employ an independent corrosion control firm to supervise installation and to perform all installation testing of the trackwork isolation system including, but not limited to, high voltage testing of rail boot material, pre-installation inspection, post installation testing of the track-to-earth resistance, post installation testing of the rail-to-rail resistance, and post installation testing of the insulating rail joints. The independent corrosion control firm shall have been continuously engaged in the field of corrosion control testing related to DC electrified transit systems for a minimum of five years and shall have the following qualifications:
1. Registered professional corrosion engineer or NACE International Certified Cathodic Protection Specialist available to manage this corrosion control project.

2. NACE International certified Cathodic Protection Specialists and Corrosion Technicians available to perform the required field-testing.

3. A minimum of five years’ experience in the testing of trackwork isolation of similar type and equal complexity as the system specified and indicated.

4. Testing shall be performed by personnel with at least five years of employment experience with testing trackwork isolation systems.

5. All equipment to be used for quality assurance testing shall bear current calibration stickers. Current calibration certificates shall be submitted for all equipment to be used for this testing.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 CONTRACT HOLD POINTS

A. Install a test section of not more than 2,000 feet of trackwork. Subsequent to the installation of the test section and prior to connection to existing trackwork, the Contractor’s Testing Agency shall perform track-to-earth and rail-to-rail resistance testing to ensure that the criteria set forth in Article 3.02, herein, are met. The Contractor shall replace or repair any trackwork found to be deficient at no additional expense to Sound Transit. Do not construct any additional track construction until the test section is accepted by the Contractor’s Quality Manager and by Sound Transit to meet the established criteria.

B. Submit weekly schedule updates indicating the track that has been installed to date and the trackwork scheduled to be installed during the upcoming week such that a testing schedule can be established by the Contractor.

C. It is the Contractor’s responsibility to clean all sections scheduled for testing of all dirt, debris, and water prior to each scheduled test. Cost of cleaning and retesting any test section found to be in unacceptable condition shall be borne by the Contractor.

3.02 TEST PROCEDURE

A. Track-to-earth and rail-to-rail resistance testing shall be performed by the Contractor. The Contractor has the option to utilize the test procedure set forth below should the Contractor choose to perform preliminary track-to-earth resistance proof-testing prior to the quality control testing. The following general test procedure are to be followed by the Contractor.

1. Take a sufficient number of readings to ensure that human error in reading the instruments and transient disturbances in the electrical network have negligible influence on the final results.

2. Obtain a minimum of three (3) measurements for each data type test.

3. Record time at which each reading is obtained.

4. Examine data at time of test to ascertain that removal of either the highest or lowest value will not alter the arithmetic average of the group by more than
5 percent. If the average will be altered by more than 5 percent, obtain additional sets of data and combine results with first set. If the average of the combined data will still be altered by more than 5 percent by removal of the highest or lowest value, an unstable condition might exist. Advise the Contractor’s Quality Manager and the Resident Engineer of unstable data conditions.

5. Perform incremental track-to-earth resistance and rail-to-rail resistance tests as soon as all major construction work is completed for that track increment. Do not defer testing to consolidate the testing effort.

6. Perform track-to-earth resistance and rail-to-rail resistance tests for all trackwork, including special trackwork areas, after track installation is completed.

7. Prior to each test, visually examine trackwork to ensure that there is no debris, water, dirt, ballast or other conductive material in electrical contact with the track. Record the condition of the track section to be tested on the data sheet.

B. Electrical Test Procedures

1. The purpose of this Article is to identify minimum electrical test requirements for track-to-earth and rail-to-rail resistance measurements. Conduct tests in accordance with the approved test plan.

2. Rail Insulating Joint Test. Test each rail insulating joint for effectiveness prior to the connection of impedance bonds by both of the following test methods.

   a. Measure the resistance between each side of the insulating joint and the joint bar and measure the resistance across the insulating joint.

   b. Measure the voltage shift of the rail to earth on both sides of the insulating joint while applying a test current to one side of the insulating joint during track-to-earth resistance testing. Measure the voltage shift across the insulating joint as well.

   c. Repair and retesting of any deficiencies are at the Contractor’s expense.

   d. Document all measurements and submit in accordance with approved test plan.

3. Track-to-Earth Resistance Test. Conduct track-to-earth resistance testing for all trackwork constructed for this project. Two test methods can be utilized for this contract to obtain the required track-to-earth resistance depending on the trackwork configuration encountered during the test period. Test sections of trackwork in maximum increments of 2,000 track feet.

   a. Track-to-earth resistance Test Method 1 pertains to electrically separated sections of trackwork. Conduct this test in accordance with ASTM G165.

   b. Track-to-earth resistance Test Method 2 pertains to electrically interconnected sections of trackwork. Conduct this testing in accordance with ASTM G165 for equipment and measurement requirements and with the following:

      1) Establish a current circuit (I1) between the track system and a low resistant earth contact and a track-to-earth voltage measuring circuit (Vg1) using a low resistance earth contact. Do not use the same earth contact for voltage circuit and the current circuit.
2) With the current circuit (I1) closed, reduce the meter ranges of both circuits until the lowest readable scales are reached. Read and record the "on" values for current and voltage.

3) Open the current circuit (I1) and immediately read and record the "off" values for current and voltage. Repeat a minimum of three (3) times for accuracy.

4) Calculate the effective track-to-earth resistance by dividing the summation of change in voltage $\Sigma \Delta Vg1$, by the summation of change in current, $\Sigma \Delta I1$.

$$R_{vg1-1} = \frac{\Sigma \Delta Vg1}{\Sigma \Delta I1} \text{ (volt/ampere)}$$

This resistance value represents the apparent resistance of the track section under test in parallel with the adjacent track sections. Usually the composite resistance to earth of the adjacent track sections will be lower than that of the test section because of the greater amount of trackage involved.

5) Obtain additional track-to-earth couplings at other locations as required.

$$R_{vg2-1} = \frac{\Sigma \Delta Vg2}{\Sigma \Delta I1} = \text{volt/ampere}$$

$$R_{vg3-1} = \frac{\Sigma \Delta Vg3}{\Sigma \Delta I1} = \text{volt/ampere}$$

6) Maintaining the current circuit (I1), measure the percentage of change in current flow on each rail each end of the test section using a maximum of 50 feet of rail as a current measuring shunt. Calculate the percentage of current flow as follows:

$$\% I_{A-1} = \frac{(\Sigma \Delta EA \times KR \times 100)}{\Sigma \Delta I1}$$

Where:

$\% I_{A-1}$ = percentage of I1 at location "A"

$\Sigma \Delta EA$ = summation of change in EA caused by I1, for the total number of readings taken (millivolts).

$\Sigma \Delta I1$ = summation of change in I1 for the total number of readings taken (amperes)

$KR$ = conversion factor for the millivolt shunt circuit (amperes/millivolt)

$$KR = \frac{1}{L \times RR \times 1000 \text{ mv/v}}$$

$L$ = length of rail used for the millivolt shunt circuit (feet)

$RR$ = longitudinal resistance of running rail per 1 foot length (ohms/foot)

Note: Using theoretical resistance values of $8.68 \times 10^{-6}$ ohm/foot for 115 lb. rail and $8.32 \times 10^{-6}$ ohm/foot for 120 lb. rail, theoretical KR values, for a 50 foot span of single rail are:
KR = 2.30 amperes/millivolt (115 lb. rail)
KR = 2.40 amperes/millivolt (120 lb. rail)

A sufficient sampling of actual longitudinal resistance factors shall be measured to establish a statistical mean value for KR used in the preceding calculations.

7) Obtain current flow percentages at the locations specified. Calculate the following:

\[ \%IB-1 = \frac{\sum \Delta EB \times KR \times 100}{\sum \Delta I1} \]
\[ \%IC-1 = \frac{\sum \Delta EC \times KR \times 100}{\sum \Delta I1} \]
\[ \%ID-1 = \frac{\sum \Delta ED \times KR \times 100}{\sum \Delta I1} \]
\[ \%IE-1 = \frac{\sum \Delta EE \times KR \times 100}{\sum \Delta I1} \]
\[ \%IF-1 = \frac{\sum \Delta EF \times KR \times 100}{\sum \Delta I1} \]
\[ \%IG-1 = \frac{\sum \Delta EG \times KR \times 100}{\sum \Delta I1} \]
\[ \%IH-1 = \frac{\sum \Delta EH \times KR \times 100}{\sum \Delta I1} \] and
\[ \%IS-1 = \%IA-1 + \%IB-1 + \%IC-1 + \%ID-1 \]
\[ \%IR-1 = \%IE-1 + \%IF-1 + \%IG-1 + \%IH-1 \]

A significant difference between the values obtained for \%IA-1 through \%ID-1 and/or between the values obtained for \%IE-1 through \%IH-1 may indicate that the electrical conductance-to-earth is not uniform over the entire track section being evaluated.

8) Calculate the average resistance-to-earth of the test section

\[ RAVG = \frac{(RVg1-1 + RVg2-1 + RVg3-1) / 3 - \%IS-1 - \%IR-1}{(\%IS-1 - \%IR-1)} \]

Where:
\%IS-1 and \%IR-1 shall be expressed as decimals

9) Calculate the average track-to-earth resistance for the test section on a 1000 foot of track basis (2 rails).

\[ RT = RAVG \times L \times 2 \text{ ohms-1000-feet of track (2 rails)} \]

Where:
L = Length of track in multiples of 1000 feet

C. Minimum Acceptable Resistance Values

1. Trackwork (All locations/types)
   a. Mainline Ballasted Track-To-Earth Resistance Values: Minimum 500 ohms per 1,000 feet of single track (two rails).
   b. Mainline Direct Fixation Track-To-Earth Resistance Values: Minimum 500 ohms per 1,000 feet of single track (two rails).
c. Mainline Embedded Track-To-Earth Resistance Values: Minimum 200 ohms per 1,000 feet of single track (two rails).

d. Yard Track-To-Earth Resistance Values: Minimum 75 ohms per 1,000 feet of single track (two rails).

e. Mainline Rail-To-Rail Resistance Values: Minimum 200 ohms per 1,000 feet of single track (two rails).

2. If the test results show that a section of trackwork fails to meet the acceptance criteria, check all instrumentation setups; verify that the equipment is operating properly; inspect the section under test for installation deficiencies, and correct the problems detected. Repair trackwork and repeat tests until the resistance values meet the acceptance criteria. Failed sections shall be clearly marked with grease pencil or rail crayon. Perform remedial work and subsequent testing at no cost to Sound Transit.

3. If test results indicate a failure to meet acceptance criteria, notify the Contractor’s Quality Manager and the Resident Engineer within two (2) days of the completion of the test.

D. Final Acceptance Testing

1. Notify the Contractor’s Quality Manager and Resident Engineer when the trackwork is ready for final acceptance Testing.
SECTION 27 11 16
COMMUNICATIONS HOUSES, CABINETS AND RACKS

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Requirements for procurement and installation of UPS house, communications houses, cabinets and racks.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. American National Standards Institute (ANSI)
   a. ANSI T1.329 Network Equipment – Earthquake Resistance
   c. ANSI 61-Gray Paint – Resistance to corrosion

2. ASTM International (ASTM)
   a. ASTM-E-84 Standard Test method for Surface Burning Characteristics of Building Materials
   b. ASTM A570 Standard Specification for Structural Steel

3. Institute of Electrical and Electronics Engineers (IEEE)
   a. IEEE-81 Grounding Fall of Potential Measurement

4. Military Standard (MIL STD)
   a. MIL Std. 285 Attenuation Measurements for Enclosures

5. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code (NEC)
   b. NFPA 130 Standard for Fixed Guideway Transit & Passenger Rail Systems

6. National Electrical Manufacturers Association (NEMA)
   a. NEMA 4 Enclosure Type

7. Telcordia
   a. GR-63-CORE NEBS Requirements: Physical Protection for Fiber Distributing Frames

9. BICSI Telecommunications Distribution Methods Manual (TDMM) Standard

10. Electronic Industries Association (EIA)
   a. EIA-310 Equipment Rack Hole Spacing

1.03 SUBMITTALS

1. Drawings:
   a. A preliminary comprehensive drawing list of all Communications houses, cabinets, and rack drawings to be created for this Contract.
   b. The initial drawing list shall contain all anticipated Communications houses, cabinets, and racks drawings that will be created as part of this Contract. Standard manufacturer drawings that are generally provided with the product or subsystem need not be included in the drawing list.
   c. Numbering of the Communications houses, cabinets, and racks drawings shall generally follow Sound Transit's numbering scheme.
   d. Each subsequent submittal after the preliminary design shall refine and update the drawing list.
   e. The final as-built drawing list shall contain all Communications houses, cabinets, and rack drawings created specifically for this Contract.
   f. Naming and numbering of devices shall follow Sound Transit's Light Rail Equipment and Facilities Numbering Plan.

2. Product Data:
   a. Houses and cabinet products specification sheets for houses, cabinets and racks.

3. Shop Drawings:
   a. Detailed arrangement plans of equipment in each house, cabinet and rack prior to rack assembly.
   b. House, room and cross passage layout installation drawings showing equipment rack and cabinet locations. These drawings shall be to scale.
   c. For all cabinets where Contractor provided equipment will be installed, conduit entry and routing drawings, including equipment installation and interconnection elevation details: Submit design of cabling methods suitable for mounting in Contractor provided cabinets or racks.
   d. Drawings showing method of power grounding conduit and cabling.
   e. Drawings and documentation indicating proposed method of mounting each piece of communications equipment component to cabinet and equipment rack, including any relocation plans of existing equipment where required.

4. Seismic conformance report for all Contractor-provided houses, racks and cases.
5. Spare parts
   a. The Contractor shall furnish and deliver the following spare parts to Sound Transit:
      1) One fiber distribution cabinet.
      2) One set of each type of distribution rack installation hardware.
      3) One set of each type of distribution cabinet installation hardware.

PART 2 - PRODUCTS

2.01 GENERAL
   A. All racks installed in Communications Systems rooms or houses shall be installed to meet Zone 3 compliance to Bellcore GR-63-CORE for Network Equipment Building Systems (NEBS). This shall be confirmed and submitted for all products either via cut sheets or in the form of a certification report from a licensed engineer.
   B. Layout of racks in the rooms and houses is conceptual. The Contractor shall provide layout drawings based on actual equipment and racks used that best facilitates installation and maintenance access.
   C. Racks and cabinets will be installed in space constrained spaces. Contractor’s design shall take this into consideration when designing the houses, cabinets or racks and determining height.

2.02 COMMUNICATION HOUSE AND UPS HOUSES
   A. Size: Size as indicated on the contract drawings.
   B. Design doors to provide a dust proof and weatherproof seal.
   C. Cover the entire floor with textured non-skid rubber matting.
   D. Provide fluorescent lighting above the aisles to provide illumination to both sides of the equipment racks, wall shelves, and the local control panel area.
   E. Environmental Controls:
      1. Provide environmental controls including air conditioning and ventilation to maintain a temperature between 60 and 78 degrees F under normal operating conditions. Assume minimum exterior temperature of 15 degrees and maximum exterior temperature to be 98 degrees F.
      2. Air filtration: MERV 9 filters minimum.
      3. Ensure air conditioner drains to the exterior of the house. Interlock thermostat controls such that heating and air conditioning cannot both be on.
      4. Provide dry contacts to monitor temperature by SCADA BMS.
   F. Fire Detection System:
      1. Thermal fire detector: Provide two thermal fire detectors with fixed temperature and rate-of-rise capabilities in accordance with UL 521.
      2. Ionization Detector:
a. Provide two ionization detectors activated by products of combustion.

b. Sensitivity: adjustable with minimum level required by UL, unaffected by rapid changes of humidity.

c. Type: UL listed, multiple use, plug-in units containing two chambers with no moving parts, and contain no material requiring licensing by the Atomic Energy Commission for this application.

d. Detector base: screw terminals, neon indicator, standard base to accommodate a thermal rate-of-rise detector without additional wiring.

3. Manual pull station: single action, in accordance with UL 38, convenient and easily accessible, activates audible and visual indicating devices.

4. Provide dry contacts for monitoring by SCADA EVS or BMS.

G. Intrusion Detection: detect opening of a door, sound an audible warning and have a dry contact for monitoring by SCADA BMS.

H. Provide keypad near front door to disable alarm an adjustable time prior to alarm sounding. Intrusion detection system shall be fed by a separate power panel breaker and have enclosed battery backup.

I. Combined fire/intrusion detector with keypad, horn battery box, four wire ionization detector and thermal detector may be used.

J. Incoming AC Components:

1. Extend conduit from disconnect to the communication or UPS house main panel board.

2. Main panel board: main disconnect circuit breaker, protects complete house load.

3. Provide surge protection for the power entrance to the house.

K. Panelboards and Circuit Breakers: In accordance with Section 26 24 12, Panelboards and Circuit Breakers.

L. Transformers: In accordance with Section 26 05 17, Dry-Type Transformers.

M. Grounding Bus: Nickel plated hard drawn pure copper grounding bus, with a minimum dimension of eight inches by eight inches by 1/2 inch thick. Drill and tap a minimum of twelve 3/8 inch holes and install twelve 3/8 inch by 1/2 inch long hex head nickel plated bronze studs with one washer.

N. Internal Ground Wire: Insulated No. 6 AWG stranded internal ground wire with green insulation.

O. Ground Rods: Copper-clad steel ground rods of the non-rusting type, as manufactured by the Copperweld Corporation, or approved equal, at least eight feet in length and at least 5/8 inch in diameter. Exothermically weld ground rod connection to ground rod, Cadweld type GR or GT, or approved equal.

2.03 COMMUNICATION ROOM AND HOUSE EQUIPMENT RACKS

A. General
1. All racks shall be provided and installed so that they are racted for Zone 3 compliance to Bellcore GR-63-CORE for Network Equipment Building Systems (NEBS).

2. Size: Sized for standard 19-inch equipment widths. The Contractor shall consider the constrained spaces in the communications bungalow and rooms and its design shall accommodate these spaces. Such accommodations may include taller racks, swing racks, pull out shelves or other means to mount equipment and meet required clearances.


5. Paint: ANSI 61 gray and resistant to corrosion.


7. Mounting Equipment.
   a. Expansion Anchors: Hilti Model HSLB M12-25 or approved equal.

   Braced to enable a seismic Zone 3 rating.

B. Server Racks

1. Shall be Chatsworth Products (CPI) Seismic-Frame© cabinet series, or approved equal.

2. Nineteen inches EIA-310-E compliant

3. Four pole, with adjustable position vertical rails


5. Design racks to accept 120 Vac single phase service.

2.04 COMMUNICATION DISTRIBUTION CABINETS

A. Cabinet Enclosure Requirements:

1. Dimensions: As indicated on the contract drawings. The Contractor shall consider the constrained spaces in the distribution cabinets and its design shall accommodate these spaces. Such accommodations may include, swing racks, pull out shelves or other means to mount equipment and meet required clearances. Full access to all Contractor provided equipment shall be provided.

2. Cabinet Enclosure: for indoor in accordance with NEMA 4 and for outdoor in accordance with NEMA 3X standard.

3. Cabinet shall be 14 gauge steel, seams continuously welded and ground smooth; no holes or knockouts.

4. Cabinet shall contain a minimum 33 rack unit frame to accept standard 19-inch rack-mountable equipment:

5. If the Contractor's design require a swing frame to accommodate the tight spaces it shall:
a. Be within the cabinet and shall be capable of swinging a minimum of 90 degrees, to provide access to the rear of equipment mounted on the frame.

b. The swing frame shall pivot within enclosure, from the right or left-hand side, as determined based on field conditions, and shall have a swing stop.

c. Rack mount holes are tapped with #10-32 threads spaced per EIA-310 standard.

d. The swing frame shall use a two-point locking rod system with double bit insert and an alignment mechanism, with a handle to pull out the frame.

e. The swing frame load capacity shall support installed equipment without affecting frame structural integrity (bending or flexing), or frame movement.

f. The frame shall allow for maximum use of the internal cabinet space.

6. In addition to required communication equipment, the cabinet enclosure shall be supplied with the following items:

a. Ground Bars.

b. Door activated interior light.

c. Door switch for operation of lighting.

d. Intrusion alarm door switch.

e. Drawing pocket.

f. Grounding straps from door to cabinet and swing rack to cabinet.

g. Mounting brackets for DIN rails.

h. Equipment shelves, mounting panels, brackets, and supports.

i. Wire management guide brackets.

j. Supervised power outlet strips.

k. Terminal strips and patch panels.

l. 120 Vac utility receptacle outlet.

7. Ventilation: Incorporate ventilation fans and Louvers into cabinet to maintain ambient internal temperature within limits of installed equipment.

8. Cabinet shall be mounted on a steel pedestal frame.

9. Front and rear of all equipment shall be accessible. If required for access removable side panels can be provided.

10. Pedestal mounting frame shall be per cabinet manufacture approval. Provide all hardware required to furnish a complete, stabilized cabinet, including any bolt-down hardware to limit tipping of the cabinet during operation and servicing.
11. Cabinet mounting and mounting hardware shall be earthquake zone 3 rating compliant.
12. Combustion: In accordance with NFPA 130 Section 5.4.2.

B. Cabinet Door.
   1. Equip doors with a device that restrains the doors in the open position.
   2. Door in closed position shall not interfere with any installed equipment, wiring, or rack frame.
   3. Equip doors with forced entry resistant doors with a three-point lock.
   4. Locks: Door handle shall accept a padlock. Locks shall be keyed alike.
   5. Seal locking device to prevent water intrusion into cabinet.
   6. Provide five master keys.

C. Cabinet Enclosure Requirements (Fire Command Center Rooms Only):
   1. Cabinet shall have removable side panels to allow access for equipment maintenance.
   2. Cabinet shall have rack mounting rails, sized for standard 19-inch equipment widths. Standard EIA-310 hole pattern with pre-tapped holes with #10-32 threads.
   4. Paint: ANSI 61 gray and resistant to corrosion.
   5. Ventilation: Louvered top panel and fan to provide air flow of 400 CFM minimum.
   6. Doors: Hinged, swing open, and removable doors.

2.05 FIBER DISTRIBUTION CABINETS
A. Enclosure.
   1. Overall Size and Layout: In accordance with the Contract Drawings.
   2. Design equipment to meet space provided.
   3. Material: 14 gauge steel welded construction
   4. Provide open cutouts on both sides, with removable casketed cover panels.
   5. Provide adjustable vertical rack mount rails, standard rack-unit spacing, interior of cabinet. Size as indicated on contract drawings.
   6. Seismic rating: Meets Zone 3 requirements in accordance with ANSI T1.329.
   7. Seams: Continuously welded and ground smooth.
   8. Cabinet support: Four wall mount feet on rear wall of cabinet.
9. Communication cable entry shall be via conduit from top or bottom of enclosure.


11. Tested in accordance with Mil Std. 285.

12. Combustion: In accordance with NFPA 130 Section 5.4.2.

13. Flame spread rating: In accordance with ASTM E-84 Class 1.

14. External mounted screws, hinges, or other fastening devices are not allowed unless approved by Resident Engineer.

**B. Doors.**

1. Non-vented front door.

2. Equip doors with reversible swing opening.

3. Equip doors with a device that restrains the doors in the open position.

4. Equip doors with forced entry resistant doors with a three-point lock.

5. Locks: door handle shall accept a padlock. Locks shall be keyed alike.

6. Seal locking device to prevent water intrusion into cabinet.

7. Provide five master keys to Resident Engineer.

8. Provide a sleeve or pocket for drawings to be housed on cabinet doors.

**2.06 VIBRATION CONTROL CABINET**

A. Hoffman Concept Series or approved equal.

B. Overall Size and Layout: In accordance with the Contract Drawings.

C. Design equipment to meet space provided.

D. Mounting holes in back of body for external wall-mount brackets.

E. Color: ANSI 61 Gray, Smooth; Interior, exterior.

F. Hardware Kit with rear panel mounting nuts, panel grounding hardware, and sealing washers.

G. Conduit entry shall be via top or bottom of enclosure.

**2.07 GROUNDING – EQUIPMENT CABINETS AND RACKS**

A. Communications Grounding shall follow “Communications Single Point Grounding System” drawing.

B. Grounds shall not exceed 5 ohms as measured by IEEE-81 Fall of Potential at the room ground bar provided in the communication facility.

C. Per NECA/BICSI 607, the maximum value for resistance between any point in the telecommunications bonding and grounding system and the building’s electrical grounding electrode system shall be 100 milliohms.
D. Any electrical ground impedance value larger than 5Ω will require the approval of the Resident Engineer.

E. Provide two ground bus bars, one for chassis and one for equipment ground.

F. Provide maximum ground protection from Radio Frequency Interference (RFI) and Electromagnetic Interference (EMI).

G. Testing for current on the Safety Ground of any end device shall not exceed 3.5ma per ITE Standard UL/CSA 60950-1_2007. Exceeding 3.5ma of current is a failure of the test.

PART 3 - EXECUTION

3.01 GENERAL

A. All Communications System elements, to include but not be limited to, enclosures, racks, and equipment that are installed by the Contractor shall be racted for Zone 3 compliance to Bellcore GR-63-CORE for Network Equipment Building Systems (NEBS).

3.02 RACK/CABINET ENCLOSURE INSTALLATION

A. Rack /Cabinet Enclosure Installation:

1. Provide equipment racks or cabinets for communications systems at locations as indicated on the Contract Drawings.

2. Provide shelves, brackets, fans, horizontal and vertical cable management, ground bars, power strips, rack screws, leveling casters, machine screws and other accessories as required for a functional installation.

3. Electrically isolate racks from one another and from cable tray. See "Communications Single Point Grounding System" diagram.

4. Prior to installation, survey sites to ensure submitted drawings accurately represent the current field condition. Make modifications to drawings to reflect actual field conditions based on survey results.

5. Install each cabinet level, plumb, and grounded per “Communications Single Point Grounding System diagram. Cabinets to be mounted material to isolate it from the floor.

6. Install wall mounted cabinets minimum 30 inches above finished floor.

7. Rack and cabinet power installations: In accordance with NFPA 70 (NEC) and local codes.

8. Ground racks and cabinets to appropriate ground system. No ground loops shall be permitted. Grounding conductor shall be in accordance with NFPA 70 (NEC), ANSI/NECA/BICSI 607-2011 and local codes.

9. Equipment rack interface with floor.
   a. Raise equipment racks off floor with Insolated I-beams.
   c. Mitigate effects of vibration conditions caused by operation of adjacent systems.
d. Firmly affix equipment in racks and cabinets to prevent damage due to vibration.

3.03 RACK/CABINET MOUNTED EQUIPMENT INSTALLATION

A. Rack mount equipment in the communication room or bungalow equipment rack or cabinet. Design mounting methods for any equipment that is not normally rack mounted.

B. Provision shall be provided to allow ease of access to front and rear of equipment.

C. Equipment shall be mounted to maximize air-flow inside cabinet.

D. Equipment shall be mounted to minimize vibration effects on equipment.

E. Equipment shall be mounted to maximize contiguous free rack space for future use.

F. Equipment and associated wires (data, power, and ground) shall be installed to allow for ease of cabinet opening, swing frame opening, and pull-out and pivot of frames. Maintenance access to front and rear of cabinet shall not, in any way, be obstructed by wiring of equipment.

G. Cables installed within cabinet shall be of sufficient length so that any swing frame or pull-out and pivot frame within cabinet can be swung out to its maximum extent without damaging any cable or straining any connector.

H. Wrap cables in bundles within cabinet in an orderly manner per functional type; arrange bundles so that cables are not damaged by the movement of any swing frame or opening/closing of any panels. Ensure wrap does not crimp cables. Bundle fiber patch cords only with Velcro type wraps.

I. Cable installation shall not exceed maximum bend radius per cable manufacture.

J. Wires shall be installed based on approved installation plans.

K. Rack mounted equipment shall be grounded to rack/cabinet internal ground bar.

L. Wires, patch cords etc., shall be installed and dressed in a manner as to prevent accidental misconnection from equipment during routine maintenance.

3.04 CLEANING

A. Clean interior of boxes to remove dust, debris, and other material.

B. Clean exposed surfaces.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes requirements for design, procurement, installation, termination, testing, labeling, and documentation of systems fiber optic cables and ancillary equipment.

1.02 REFERENCES

A. ASTM International (ASTM)


B. Institute of Electrical and Electronic Engineers (IEEE)


C. International Organization of Standardization (ISO)

1. ISO 9001 Standard Quality Management Systems

D. National Fire Protection Association (NFPA)

1. NFPA 70 2014 Edition National Electrical Code (Chapters, Articles, and Sections that impact telecommunications installation)

2. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

3. NFPA 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Spaces

E. Naval Engineering Standard (NES)

1. NES 711 Smoke

2. NES 713 Toxicity

F. Telecommunication Industry Association/Electronic Industries Alliance (TIA/EIA)

1. TIA/EIA 455-B Standard Test Procedure for Fiber Optic Fibers, Cables, Transducers, Sensors, Connecting and Terminating Devices, and Other Fiber Optic Components


3. TIA/EIA 455-124 Polarization-Mode Dispersion Measurement for Single-Mode Optical Fibers by Interferometry
4. TIA/EIA 455-175B Measurement Methods and Test Procedures Chromatic Dispersion
6. TIA/EIA 598 Fiber Optic Color Code
7. TIA/EIA 568-B.1-2 Commercial Building Cabling for Telecommunications Products and Services
9. TIA/EIA-569A Commercial Building Standard for Telecommunications Pathways and Spaces
10. TIA/EIA 568-C Cabling and components standard
11. TIA-758B-2012 Customer-Owned Outside Plant Telecommunications (OSP)

G. Telcordia
1. GR-449-CORE Generic Requirements and Design Considerations for Fiber Distributing Frames
2. GR-20-CORE Generic Requirements for Optical Fiber and Optical Cable Specifications

H. Underwriters Laboratories (UL)
1. UL 224 Extruded Insulating Tubing
2. UL 910 Test for Flame-Propagation and Smoke-Density Values for Electrical and Optical-Fiber Cables Used in Spaces Transporting Environmental Air
3. UL 1666 Test for Flame Propagation Height of Electrical and Optical-Fiber Cables Installed Vertically in Shafts

I. BICSI TDMM 13th Edition

J. FOA
1. Standards FOA1 Testing the Loss of a Fiber Optic Cable Plant and Standard FOA4 OTDR Testing a Fiber Optic Plant

K. American National Standards Institute (ANSI)
1. ANSI/TIA-568-C.3 Optical Fiber Cabling Components

1.03 SUBMITTALS

1. Drawings
   a. The initial drawing list shall contain all anticipated Optical Fiber Cabling System drawings that will be created as part of this Contract. Standard manufacturer drawings that are generally provided with the product or subsystem need not be included in the drawing list.
b. Numbering of the Optical Fiber Cabling System drawings shall generally follow Sound Transit’s numbering scheme.

c. Each subsequent submittal after the preliminary design shall refine and update the drawing list.

d. The final as-built drawing list shall contain all Optical Fiber Cabling System drawings created specifically for this Contract.

e. Naming and numbering of devices shall follow Sound Transit’s Light Rail Equipment and Facilities Numbering Plan. An Equipment and Facilities plan by the contractor shall be submitted and approved before any Fiber testing and installation can proceed.

2. Product specification sheets.

3. Design Reviews:
   a. Preliminary Design Review.
   b. Final Design Review.


B. Site Survey Report:

1. Survey signal/communications ducts, manholes, and handholes to determine most suitable fiber cable installation method, based on field conditions and duct occupancy. Submit:
   a. Assessment of suitability of duct bank, inner ducts, conduits, and general site conditions for the installation of cables and equipment.
   b. Duct bank and inner duct occupancy drawings.
   c. Duct plan drawings with distance indications.
   d. Manhole and handhole location drawings will be submitted with numbering and labeling per the approved plan.

   Survey existing equipment rooms and fiber distribution equipment installed by others. Submit:
   e. Existing fiber distribution cabinet and rack layouts including feasibility for expansion.
   f. Existing fiber optic backbone cables and bulkhead port utilization.
   g. Spare capacity for existing fiber bulkhead ports and feasibility for expansion.

C. Design Document.

1. Technical Data Sheets - Submit complete technical data sheets for the fiber cable and ancillary equipment proposed. Demonstrate compliance with mechanical and optical properties specified herein.

2. Manufacturer Experience - Submit information for each proposed manufacturer describing his experience in manufacturing fiber optical cable, splice equipment,
and termination equipment for rapid transit and railroad applications and quality assurance program and warranty.

3. Contractor Experience - Submit information for each proposed fiber contractor describing his experience in installation and testing of fiber optical cable, splice equipment, and termination equipment for rapid transit and railroad applications and quality assurance program and warranty.

4. Fiber Cable System Plans and Drawings - Submit fiber cable system schematic, plan, and detail drawings, indicating complete fiber cable system, cable lengths, equipment placement within station and cross-passages. Include profiles showing location of cabinets/racks, rack elevation drawings, including all fiber termination details. Specify cable fiber cable labeling in accordance with Sound Transit existing standards.

5. Calculations - Submit calculations for each fiber optic cable span and fiber link budget calculations.

6. Material/Equipment/Assembly/Installation Details - Submittal shall include materials, equipment, assembly and installation required to carry out functions and purposes indicated in these Specifications, and to make the system suitable for the purpose for which it is intended, whether or not such materials, equipment, assembly and installation are specially indicated in the requirements of these Specifications.

7. Cable Interface Diagrams - Design submittal shall define fiber patch cable interfaces between systems. This includes communications, radio, signal, traction power, and 26 kV.

8. Termination and Splicing Instructions - Submit approved step by step termination, connector, and pigtail splicing instruction in accordance with manufacture supplied documentation for fiber optic equipment to be utilized as part of the fiber cable system.

D. Fiber Cable Installation/Pull Plan.

1. Submit Installation plan as outlined herein. Plan to include existing and new conduits selected for fiber installation to be mandrel / clean swabbed prior to use. This shall be completed early in the schedule to allow for corrections if needed

E. Fiber Test Equipment.

1. Submit Manufacturer cut sheets and user documentation for fiber optic test equipment and test viewing software to be utilized as part Fiber optic installation and testing.

F. Testing Documents.

1. Submit Test Program Plan, Test Procedures, and Test Results for each Test.

2. Factory Production Test: Submit Certified Test Report prior to shipment.

3. Pre-Installation Reel Test: Submit Fiber Cable Reel Test Report after shipment, but prior to Installation.

4. Fiber Cable Termination/Splicing Testing: Submit test results for individual pigtail splices in accordance with approved procedure.
5. Fiber Cable Field Tests: Submit end to end test results of OTDR and Power Meter tests in accordance with approved procedures.

G. Spare parts

1. Provide spare SC bulkhead connectors, panels, SC-APC pigtail assemblies, splice trays, and splice sleeves compatible with the Fiber Distribution Panels as specified herein. Provide for a total of 72 spare fiber splice/terminations.

2. Provide spare fiber patch cords for Intra-FDP, FDP to FDP, and equipment to FDP connections as specified herein. Provide number patch cords equal to 3% of the total of traffic carrying patch cords installed per final acceptance of the network communications requirements. Patch cords lengths and connector types to be site specific per equipment requirements.

1.04 QUALITY ASSURANCE/QUALITY CONTROL (CABLE MANUFACTURER)

A. Wire and cable manufacturers, quoted products and installation vendors shall be approved by Resident Engineer. Provide qualification data and make arrangements for required demonstrations and tests.

B. Qualifications.

1. Past Performance and Experience: Cable manufacturers shall demonstrate previous successful experience in supplying wire and cable specified herein. Provide a list of three such installations of similar size and scope for each cable manufacturer to be considered.

2. Quality Assurance Program: Cable manufacturers, in accordance with requirements of these Specifications, are required to have in place or implement, an effective quality assurance program adhering to the requirements of ISO 9001 to ensure purchase control performance. Resident Engineer reserves the right to audit the manufacturer's facilities for conformance to the Contract including, but not limited to first article inspections, source inspections and on-site surveys. Prime concern shall be focused on formal assurance requirements to ensure manufacturer cannot attribute cable failure to actions or lack of actions.

3. Technical Data: Provide technical data that demonstrates compliance with the requirements of these Specifications for each cable type Contractor plans to supply (i.e. White Papers, Certifications).

4. Factory Design Tests: Make arrangements with prospective cable manufacturers to perform factory design tests as required by Resident Engineer.

5. Sample Specimens: If requested, furnish Resident Engineer sample specimens in 4 foot lengths identical to proposed cable including connectors and peripherals. Sample specimens shall remain property of Sound Transit.

6. Manufacturers shall certify compliance with the following warranty prior to selection:

   a. Manufacturers warrant that design, material, and workmanship incorporated in each item of cable is of the highest grade and consistent with established, and generally accepted, standards for aerial and underground cable for transit applications; and that each such item and every part and component thereof shall comply with these Specifications.
b. Manufacturers agree this warranty shall commence with acceptance of each item of cable, whether defect be patent or latent, and shall continue for a period of 8 years after initial satisfactory operation of the item or 10 years after acceptance of item, whichever is shorter.

C. After Manufacture Selection.

1. Monitor manufacturers of cable to assure that approved Quality Assurance Program is being closely adhered to and that wire and cable are being manufactured in accordance with these Specifications and approved submittals.

2. Each finished cable shall be traceable to test date on file for each step in its manufacturing process.

D. Inspection and Certification Process.

1. Resident Engineer and Sound Transit systems engineers shall have the right to make such inspection and tests as necessary to determine if the cable meets requirements of these Specifications.

2. Resident Engineer and Sound Transit systems engineers shall have the right to reject cable that is defective in any respect.

3. Provide Resident Engineer 15 Days advance notice of date cable will be ready for final testing so that Sound Transit may witness the tests, if it so elects. With the notice, a copy of the specific test forms will be supplied with all the cable, test equipment, and fiber cable numbers/labeling, persons preforming the tests and relative test information on the forms.

4. Physical Tests: Perform physical random tests on samples selected at the place of production. Take each test sample from accessible end of different reels. Identify each reel selected with corresponding sample. Specify number and length of samples under individual tests. Perform tests for cable materials and cable construction specified.

5. Resident Engineer reserves the right to conduct any test to provide further satisfaction that cable is manufactured in accordance with requirements of these Specifications.

1.05 QUALITY ASSURANCE (QUALIFIED FIBER INSTALLATION AND TEST PERSONNEL)

A. Fiber optic work required to be performed requires a contractor with specialized knowledge and training. Contractor shall be certified by an accredited training organization, and have been and approved contractor by the following Telco or fiber cable Providers:

1. BICSI (Building Industry Consulting Services Intl), FOA (Fiber Optic Association).

2. AT&T, Verizon, or Sprint Approved Contractor with Tier 2 Certification.

3. Corning Cable Systems Trained.

B. Fiber optic cable contractors shall be well trained, experienced and qualified to perform fiber optic cable splicing. To be considered for approval for fiber optic work, the installer/splicer shall be recommended by the fiber cable manufacturers, have had recent satisfactory experience in performing all aspects of fiber optic work, with a minimum of 15 years of field experience.
C. Fiber Contractor shall have verifiable experience in the following aspects of Fiber optic work:

1. Complete fiber optic splicing (fusion and/or mechanical).
2. Complete testing services, such as end to end, reel testing, and splice loss testing, ORL, power meter/laser source testing and fiber characterization testing (10GigE certification).
4. Emergency restoration and in-service "hot cuts", Balloon-lateral splices.
5. Rodding & Duct proofing, inner-duct installation.
6. Installation within underground ducts/manhole environments, Certified in Confined Space Entry.
7. Place fiber cable -- all sizes.
9. Experience working within active Transportation Right of ways-including constrained working hours.

D. If during any process involving fiber optic cable work the Resident Engineer determines the fiber installation/splice personnel are found to exceed the listed reasonable average time periods of work performance for a given task for no cause, and installation schedules are being affected, the Contractor shall be required to replace installer/splice personnel with more capable personnel that shall complete the installation and splicing work in the prescribed time period at no additional expense to Sound Transit.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Packing, Handling, and storage

1. Cables shall be properly packed, handled and stored according to the manufacturer’s specifications. ST shall receive proper documentation of the chain of custody of the material from the Resident Engineer and shall be reviewed by Sound Transit systems engineers.

B. Marking

1. Mark each reel on outside flange with the following information:
   a. Manufacturer's name.
   b. Contract name and number.
   c. Cable identification number.
   d. Cable length.
   e. Date of manufacture.

C. Delivery
1. Inspect cables at time of delivery at construction site to assure no damage was done during shipping.
2. Inspect every reel for physical damage.
3. Submit to Resident Engineer cable reel inspection report.
4. Replace damaged or rejected cable promptly at no cost to Sound Transit.

D. Storage
1. Store cables on solid surfaces designed to support cable reels which drain adequately and do not allow accumulation of liquids, oils, or chemicals.
2. Align and protect cable reels so as not to allow reel flanges to damage other reels.
3. Provide adequate aisles and barricades to allow accessibility and to prevent construction equipment from damaging cable reels.
4. Reseal cable ends promptly when a length is cut from reel.

E. Handling
1. Handle cable reels using a sling and spreader attached to a shaft through the reel hubs, or by cradling both flanges between lift truck forks.
2. Do not lift reels by top reel flange or drop from any height.
3. Ensure lift truck forks do not touch cable surfaces on reel.
4. Roll reels in the direction opposite the cable wind on reel.
5. Do not lay reels flat.

PART 2 - PRODUCTS

2.01 FIBER OPTIC CABLE

A. The installation environment will include existing Link communications system facilities, underground and tunnel duct-banks, embedded and surface conduit, communications manholes and handholds, cross-passages, and station systems equipment rooms.

B. General
1. Fibers shall be usable and meet required specifications.
2. The life expectancy of the cable shall be 25 years for service in a railroad and transit environment.
3. The cable shall be designed for installation in underground conduit, wet or dry environments, including alternating wet and dry conditions.
4. Fillers: Solid polyethylene, or similar material, rods of same diameter as buffer tubes.
5. Identification:
a. Cable Print: White, indented into outer jacket.

b. Apply cable print to outer jacket with the following information:

c. Cable Manufacturer.

d. Number of Fibers.

e. Fiber Type, Single Mode Fiber (SMF).

f. LSZH.

g. Date Coded Month Year (MMYY).

h. Sequential Marking (a mark every foot or meter).

C. Application Descriptions.

1. Fiber count per Contract drawings.

2. General: Manufacture Draka DLSZHB Heavy Duty Duct Cable, or approved equal.

3. Radio fiber – rating: OFNR/OFN, CSA FT4; suitable for field connectorizing to APC connectors for direct connection to radio equipment.

2.02 FIBER SPLICE CASE

A. Provide splice cases suitable for: underground manhole cable vaults, outside plant, uncontrolled environments or at building entry point when space permits. Splice cases shall be placed at locations as shown on Contract drawings.

B. Approved Manufacturer: Preformed Line Products, 3M, Corning, or approved equal.

C. Uncontrolled Environment: Location in which temperature and humidity are not artificially regulated, where relative humidity can exceed 50 percent, or where liquid may come into contact with the fiber cable core.

D. Construction: Cylindrical design having two points of entry (one in each end of the cylinder) for at least four cables in each point. Splice cases shall be re-enterable and re-sealable to support fiber cable repair and or expansion.

E. Entry Points: Flexible compression type fitting having a single compression gasket between two type 304 stainless steel plates.

F. Environmental Requirements: Withstand submersion up to a depth of 10 feet for a period of 10 Days without leaking, withstand three repeat blows of 9000N without failure or leakage via submersion test.

G. Material: Corrosion resistant material equal to or superior in corrosion resistance to type 304 stainless.

H. Fill: Dry-type encapsulates to allow future re-entry and prevent water incursion, no gel type.

I. Size: Provide up to 288 single-fiber splices. Provide storage room for unspliced express fiber buffer tubes pass through. Support Ring Cut, loop-through splicing.
J. Supply splice case mounting hardware such that case may be secured to installation location and that cables have sufficient strain relief to prevent damage under frequent movement and harsh conditions.

2.03 FIBER DISTRIBUTION PANEL - RACK MOUNT

A. Utilize Fiber Distribution Panel (FDP) for termination, storage and distribution of the fiber optic cable system, and provide a convenient point for splicing outside plant fiber optic cables to pigtailed FDPs shall be a complete system of components by a single manufacture.

B. FDP shall comply with Telcordia GR-449-CORE.

C. Provide FDPs capable of terminating 12, 24, 36, 48, or 144 fibers strands, as shown on Contract Drawings. Final FDP port quantities in accordance with final design of fiber cable termination requirements.

D. Size: Chassis (width: 17.4 inch) x (depth: 12.0 inch) x (height: min. 1.75 inch, max. per FDP port quantities). Housing shall be rack mountable per EIA-310, in either 19 inch or 23 inch wide rack rail spacing.

E. Furnished fully loaded FDP complete with subscriber connector (SC) bulkheads, pigtailed: SC Ultra Polish Connector (UPC) pre-connectorized to 900µm jacket, color coded per TIA/EIA-598, heat shrink fusion splice trays, a splice drawer, cable rubber clamps, and FDP front cover.

F. FDP shall incorporate labeling provisions that correspond to each fiber port location. Labeling shall be viewable from front of FDP.

G. All connectors and accessory items to be compatible with new and existing optical fiber transmission equipment.

H. Outside plant cables shall be routed to the fiber panels and secured to the outside of the chassis, FDP shall provide for tie point for securing fiber cable central member.

I. Route each optical fiber into the chassis and splice tray for splicing into a pigtail assembly.

J. Sharp edges in areas where fiber may be damaged in/out of FDP is prohibited. Cable entrances shall have grommet and cable clamp strain relief.

K. Completed splices shall be mounted in splice trays for protection. Splice trays shall be capable of securely holding up to 24 individual fusion splices.

L. Splice trays, pigtailed and optical fiber buffer tubes shall be stored at the bottom of the FDP in extendable splice draws. The FDP shall be furnished with Cable Management Trays (CMT) where fiber bulkhead plates are mounted, trays shall be swing out design for access to front and rear of fiber bulkhead terminals.

M. Each CMT shall store at least 8-10 meters of fiber optic pigtailed, patch cords or a combination thereof.

N. Bend radii inside the CMT shall be greater than 2 inches.

O. The FDP shall protect the fiber throughout the panel.

P. Provide protective dust caps for all fiber ports.
Q. Accessibility for Fiber Splice Trays, Cable Management Tray, and Fiber Ports shall be from the front. Rear panel shall be removable.

2.04 FIBER DISTRIBUTION PANEL (FDP)-WALL MOUNT

A. Provide Two Door wall mount chassis fiber cable termination/splice box.

B. Terminations: Provide fully loaded 48 terminations with 8 required bulkhead plates, 6 ports per plate.

C. Bulkhead Plates: 6 Ports with SC bulkhead adaptors and 6 SM SC/UPC 900µm color coded per TIA/EIA-598-connectors/pigtails.

D. FDP shall incorporate labeling provisions that correspond to each fiber port location. Labeling shall be viewable from front of FDP.

E. Provide required splice trays for complete installation of 48 terminations.

F. Provide cable clamps, compression fittings, and strength member tie-off to support the number of fiber cables that will be terminated in the FDP.

2.05 OPTICAL FIBER PIGTAILS, PATCH CORDS, AND CONNECTORS

A. FDP Fiber Pigtails.

1. Single-Mode Pigtails with SC connector at one end and the other bare jacketed fiber.


3. Insertion Loss: Maximum 0.20 dB.

4. Return Loss: Maximum minus 55.0 dB

5. Pigtail length shall be sized per field install conditions for each FDP location, 3 meter minimum.

6. Pigtail fibers shall be provided in bundle of up to 12 fibers, individually jacketed with a 900um tight buffer, color-coded in accordance with TIA/EIA 598 Fiber Optic Color Code.

7. Pigtail fibers shall meet the same physical and optical characteristics of the fiber cable strands that it will be spliced to.

B. Manufactured Fiber Cable Pigtail Assemblies.

1. A manufactured pigtail assembly may be utilized to provide connectivity from a FDP to a separate field splice enclosure, such as a fiber splice case located in a communications manhole. The assembly shall allow the connection of FDP’s to fiber a cable backbone cable via a drop cable assembly. Splicing of the drop cable to the mainline backbone cable shall be performed within the splice case. When utilizing a fiber cable pigtail assembly, FDP tray splicing is not to be done.

2. The manufactured pigtail assembly shall be constructed so as to be installed in conduit, and shall meet the fiber cable requirements as specified within this contract.
3. Manufactured Pigtail assemblies shall be designed, ordered, pretested, for the specific location that it will be utilized. Excessive cable length in the assembly shall not be permitted.

4. Cable Loop: Maximum 20 feet.

C. Fiber Patch Cords.

1. Fiber patch cords shall be cable assemblies consisting of flexible with SC compatible connectors. Patch cords shall be complete factory fabricated assemblies from manufacturer's standard products lines.

2. Provide fiber patch cords as required for the following applications:
   a. From port to port within same FDP, for fiber cross-connection patching.
   b. From Network switch equipment optical ports to FDP, to support Link Communications Networks deployment, for both TCN and EFN. Coordinate with Sound Transit IT department.
   c. From 26 kV switchgear equipment to FDP.
   d. From TPSS equipment to FDP.
   e. From signal equipment to FDP.

3. Single-Mode Duplex Zip cord type, ADC Krone or approved equal.

4. Patch Cord Cable Construction: Shall allow for small bend radius for installation in space-constrained areas. Shall contain a dielectric strength member and a protective outer jacket.

5. Patch Cord Jacket Color: Yellow for single mode.

6. Connector shall be SC UPC (blue) for FDP ports, connector ends for field equipment ports.

7. Patch cord optical fiber shall meet the same characteristic requirements of the distribution panel terminated cable to which it mates.

8. Patch cords installed within ladder tray and at conduit to equipment transitions shall be installed in flexible corrugated innerduct for protection.

D. Radio Equipment Interconnect Connectors

1. Field Installable Angle Polish Connector (APC) SC connectors, color green, 3M or approved equal. Connectors compatible with radio equipment.

2. Single piece, pre-assembled design.

3. Manufacture supplied connector finishing tool, with fiber holder.

4. 900um buffer strain relief.

5. Factory-polished fiber stub in ferrule.

6. Keyed, angle cleave splice for APC.

7. Insertion Loss: Maximum 0.30 dB.
8. Return Loss: Maximum minus 65.0 dB.

2.06 INNERDUCT

A. Constructed of flame retardant PVC material and shall meet the following flammability requirements:

1. Inside building horizontal ladder tray, and inside building riser inner duct shall meet the UL 224 flame test.

2. Outside Plant (OSP), inner duct installed in tunnel or air plenum environment shall be LSZH, meet BSR/UL 224, and NFPA 130.

B. OSP innerduct shall be installed in embedded signal/communications (SC) conduits and duct banks where required.

1. OSP innerducts shall be 1.25-inch. OSP innerduct shall include the following features:
   a. Constructed of semi rigid flexible halogen free tubing with longitudinally ribbed inner wall, smooth exterior walls.
   b. Furnish with factory installed nylon pull ropes.
   c. Suitable for pulling into conduit/ducts and provided with fittings/connectors necessary to make up a complete raceway system. Innerduct system with connectors/fittings shall be suitable for blowing fiber at a pressure of 125 psi.
   d. Reel lengths shall be provided as necessary to ensure that ducts are continuous; one piece runs from maintenance hole/hand hole to maintenance hole/hand hole. No innerduct connectors are allowed between maintenance holes/hand holes.
   e. Pulling accessories used for innerduct shall be compatible with materials being pulled. Accessories shall be furnished as required to complete the installation, including but not limited to, innerduct lubricants, spreaders, applicators, grips, swivels, harnesses, and line missiles.

2. Station Equipment Room Cable Tray Innerduct.

   a. All fiber optic cable in raceway shall be installed in innerducts.
   b. Inside building horizontal/cable tray innerduct suitable shall be flexible corrugated type.
   c. Utilize corrugated horizontal innerduct for fiber optic patch cords installed from systems equipment to fiber distribution panels.
   d. Inner Diameter: 1 inch minimum, compatible with fiber patch cords installed within.

C. Acceptable Manufacture: Carlon, Pyramid, or approved equal.

2.07 IDENTIFICATION TAGS

A. Material: Plastic, heat-shrinkable radiation cross-linked, thermally stabilized, flame-retarded modified polyolefin sleeves.
B. Label: List device or terminal block destination and origin, and cable number. Utilized Sound Transit Link System Station Identifier and existing fiber cable label scheme in accordance with Sound Transit Light Rail Equipment and Facilities Numbering Standard.

C. Sleeves: Smear resistant prior to shrinking, achieve mark permanency when shrunk without the need for permatizing equipment, or when standard ballpoint pens or high-carbon content fabric ribbons are used.

D. Chemical Resistance: Resistant to common industrial fluids including but not limited to, Freon TF, isopropyl alcohol, and Ethylene Glycol.

E. Tags will be available and installed by/during testing. Tags for connectors will be installed before fusing onto cables. Testing will not proceed without labeling.

2.08 FIBER CABLE FACTORY TESTS

A. Provide certified test reports for each fiber cable type, per the following standards:
   1. NFPA-130.
   2. Telcordia GR-20-CORE.
   3. EIA-455-B
   5. NES 711/713 smoke/toxicity index.
   6. UL 910.
   7. NFPA-262.

B. Factory Production Tests: Provide certified test reports for each cable on-reel prior to shipment. These tests shall be performed in accordance with TIA/EIA-455-B.
   1. Record end to end loss for each fiber at 1310 nm and 1550 nm for single mode.
   2. Provide OTDR trace with both soft trace file, and hardcopy record for each fiber strand.
   3. Record cable footage, in accordance with markings and in accordance with OTDR trace.

PART 3 - EXECUTION

3.01 INSTALLATION PLAN

A. Develop a written cable installation procedure and check-off list for approval prior to cable installation in accordance with TIA/EIA 568-C and TIA/EIA-569-C.

B. Submit information for each segment of cable to be installed.

C. Site Verification – Site Survey Report
   1. Verify cable lengths through field verification.
   2. Prior to installation, verify conduits, inner ducts, and general site conditions are suitable for the installation of cables and equipment. Verify conduit size, conduit
fill, conduit bend radii, manhole spacing, manhole size, raceways, ducts, and associated hardware are proper for the intended installation.

3. Verify required cable length for each cable run prior to installation. Civil stationing appearing on referenced drawings may be used for defining locations and estimating cable lengths. Do not use existing drawings to determine final lengths and cuts. Determine actual lengths by making on-site inspections and measurements.

4. Verify installation design is correct and adequate for cables to be installed.

5. The contractor shall be required to verify condition of available spare fiber and fiber distribution panels at UW Station, International District Station, OMF, OMSF, BDC, East Link and North Link stations.

D. Provide installation plan based on site verification activities and in accordance with Section 01 12 16, Work Sequence.

E. Fiber Cable Installation Work Plan to include but not be limited to:

1. Pulling or blowing fiber cable into duct-banks, conduit, and inner-duct.

2. Installing and dressing cable into ladder trays, fiber racks/cabinets, and fiber terminal equipment.

3. Splicing fiber cable in FDP fiber panel splice trays.

4. Site Location: Describe and diagram installation area.

5. Provide list of Materials and Equipment to be installed and used.

6. Chronological Plan: List order of cable installation, including estimated time for each cable pull.

7. Plan shall indicate a reasonable average time period to perform each task.

8. Pulling Layout: Provide distances and pull tension calculations for each fiber cable at each section of installation.

9. Installation Methods: Use least damaging installation method to install cables in order to ensure maximum cable life and maintainability.

10. Innerduct: Where specified and where practical use innerduct within larger ducts to: optimize conduit usage, prevent damage to cable, and allow for fiber blowing installation methods. Innerduct shall be compatible with fiber cable installed within.

11. Slack Cable: Design installation with 50-foot slack coils at either end of cable run, and at splice locations.

12. Bend Radius: Minimum 10 times the diameter of cable or manufacturers' recommended minimum bending radius, whichever is greater.

13. Set Up and Pull Locations: Protect cable on reel and in slack loops. Protect cable after working hours where cable installation is not completed during a single shift.

14. Pull/Blowing Lengths: Allow a 20 percent margin in cable tensile strength. Do not exceed the lesser of 80 percent of the cable's maximum tensile rating or 600 pounds during installation. Identify assist points for blowing cable.
15. Maximum Vertical Rise: Calculate distance over which cable is self-supporting. Provide cable strain relief at top of each vertical rise and every time 80 percent of vertical rise rating of cable is exceeded.

16. Dynamometer: If a winch or pulling machine is used during installation, use a dynamometer to monitor cable tension. Provide pulling equipment and tension monitoring device list.

17. Drawings: Provide a detailed cable plan for each cable pull.

18. Provide proper procedures for feeding cable into conduit, to maintain proper bend radii and minimize friction.

19. Innerduct: Provide innerduct compatible with fiber optic cable installed within.

F. Contacts: Provide company name of installer, and name and contact information (cell phone) of site supervisor to Resident Engineer.

G. The Contractor’s plan shall demonstrate that, for through-substrate penetration firestop systems, in rooms that contain a clean agent fire protection system, the Contractor shall furnish and install products using a method that complies with NFPA 2001, Section “Enclosure Inspection, and Appendix C “Enclosure Integrity Procedure.”

3.02 FIBER CABLE INSTALLATION

A. General

1. Provide cable as indicated in the Contract Drawings.

2. Install cable in accordance to submitted installation plan.

3. Provide Resident Engineer 48 hours’ notice, prior to installing cables.

4. Cable Installation within Ductbanks: Install cable in SC conduits as shown on Contract Drawings. If field conditions prohibit the use of the Sound Transit designated duct, select a duct for use and coordinate selection with Resident Engineer prior to cable installation.

5. Installation Methods: Utilize the least damaging installation method to install cables in order to ensure maximum cable life and maintainability. Preferred methods shall include:
   b. Cable Pulling – Hand Pull, or Winch and Capstan methods.
   c. Cable Laying – In cable trays.

6. Use of Innerduct: Provide inner duct within larger ducts to optimize conduit usage and prevent damage to cable both in current installation and in future installations. Provide smooth-wall/ribbed inner-duct to reduce friction. Apply Pneumatic couplers during cable blowing installation methods.

7. If existing communication cables are already installed within a duct without innerduct, pull new cable into duct (also without innerduct) alongside existing cables, provided that the new cable can be pulled without damage to itself or to other existing cables already in place.

8. Conduit fill ratio for all cable pulls in ducts is not to be exceeded.
9. Material and workmanship shall be of the highest quality assuring durability for minimum life expectancy of 40 years.

10. Replace cables damaged during installation at no cost to Sound Transit.

11. Provide conduit to connect Sound Transit furnished raceways to equipment, enclosures, and devices.

12. Provide installation hardware to route, support, terminate, and protect cable installation.

13. Provide service loops sufficient for maintenance and free movement of attached electrical equipment.

14. Vertical Rise: Ensure no residual tension remains on cable after installation except due to cable weight in a vertical rise.

B. Installation in Conduit or Ducts

1. All Contractor provided conduits and raceways, inspect, mandrel, swab, and clean conduits and ensure a clean, smooth, concentric interior surface prior to cable installation.

2. Before any wire or cable is pulled into a conduit, a ball, the diameter not less than 85 percent of the nominal diameter of the conduit, shall be pulled through the conduit from one end to the other.

3. If any one of the existing ducts mandrelled in accordance with these specifications is obstructed so that more than 60 minutes is required in attempting to clear the obstruction in a length of duct between adjacent manholes, bring the obstruction to the notice of the Resident Engineer. The Resident Engineer shall verify the duct obstruction and notify the Contractor to proceed with one of the following:
   a. Rod obstructed duct.
   b. Utilize alternate duct.
   c. Remove unused cable from duct and rod duct.
   d. Install cable by alternate method.

4. Clean manholes and determine location of pulling eyes prior to cable installation.

5. Use lubrication when pulling cables into conduit, pipe, or duct bank.

6. Avoid crossover of cables pulling cables.

7. Do not pull tight or kink cables in conduit fittings or boxes.

8. Pull cables installed in a single conduit simultaneously.

9. Fiber optic cable pulling equipment shall include a dynamometer to indicate the pulling force in pounds.

10. Pulling force shall not exceed 90 percent of the maximum allowable installation tension as specified by the fiber optic cable manufacturer.
11. When utilizing pulling methods, the pulling speed of the fiber optic cable shall not exceed 20 meters/minute.

12. Any excess slack between a winch and the cable reel shall be taken up slowly. Maintain an even speed ensuring constant turning of cable reel without surging or jerking.

13. Continuously monitor cable tension with dynamometer or approved equal during cable pull.

14. Dynamometer: Certify dynamometer as calibrated and able to hold peak value of cable pull. Record peak pull value and submit as part of test results.

15. Fit conduit ends with plastic bell ends.

16. Ensure manholes have proper storage hangers for fiber slack.

17. Seal all unused or partially used conduits and Innerduct.

C. Air-Assist Cable Jetting

1. Utilize air assisted cable jetting methods for fiber cable installation, within sealed continuous innerducts.

2. Install innerducts as needed for proper Air-Jetting installation of fiber cable, utilize existing innerducts where available.

3. Verify proper installation of innerduct system utilizing pressure tight duct splice fittings, in accordance with innerduct manufacture requirements.

4. Perform duct pressurization test, by sealing one end of the duct and pressurizing the duct using a sealed blowing machine.

5. Clean, dry, and prove the duct. If it was not done previously, blow through a hard mandrel to establish that the duct is not crushed.

6. Blow a tight fitting foam carrier through the duct at high pressure. The foam should travel through at approximately 100 foot/second in a clean duct. If excess water or dirt comes from the duct, repeat the process. If necessary, dry the duct with dry airflow.

D. Installation Field Conditions

1. Pump water out of manholes or other enclosures before installing any cables.

2. Pumping water out of manholes and removal of mud, silt and debris, if required, shall be done by the Contractor, at Contractor's expense.

3. Provide the necessary power and pumping equipment.

4. Keep manholes or other enclosures or ducts clear of water during cable installation.

5. Water in manholes and handholes to be handled in accordance with state and local regulations, at Contractors expense.

E. Special Protection
1. Secure fiber cable slack, and splice cases to wall of manhole on approved cable
racking device. Fiber optic cable and enclosures shall be properly secured in a
manner which will not obstruct the installation of future communications cables
within the manhole.

2. Provide appropriate special protection for cables in areas where cables are un-
avoidably exposed to hazardous conditions such as vibration or sharp corners on
equipment.

3. Protect fiber optic cables during installation while cables are exposed in-between
work shifts.

4. Replace, at no additional cost to Sound Transit, any existing or new cable which
is damaged as a result of failure to provide such special protection.

F. Sealing

1. Seal cable entrance openings in equipment enclosures, rooms, and junction
boxes with either a compression type fitting or pliable sealing compound after the
cable is in place.

2. Use sealing compound seal area around cable where cable emerges from
conduit, pipe or duct bank. Seal or cap spare conduits.

G. Installation in Trays or Troughs

1. Lay cable loosely, neatly, and with a minimum of crossovers.

2. Do not pull cable in trays or troughs.

3. Do not pull tightly around bends.

4. Install dividers to segregate cables of different media types.

5. Route cables between racks or cabinets in overhead cable trays.

6. Provide one foot of slack between the cable tray and each rack to which the
cable is connected.

7. Secure cable to last strap of cable tray before transitioning to equipment racks or
cabinets.

3.03 INNERDUCT INSTALLATION

A. General: Install inner duct in each conduit as indicated on the Contract Drawings. Where
multiple inner ducts are required in one conduit, pull innerducts at the same time.

B. Pull Rope: Install in each inner duct, double back 2 feet of pull rope at each termination.

1. Install pull rope or cable having a minimum tensile strength of 225 kg (500
pounds).

2. Double back 600 mm (2 feet) of pull rope at each termination.

3. The use of nylon rope for pulling cable is prohibited.

C. Couplers:
1. Use couplers to mechanically and pneumatically connect two pieces of innerduct without reducing the inside diameter of the inner duct.

2. Install lubricated pull tape or line in unused inner duct.

3.04 FIBER SPLICING AND TERMINATION

A. Splicing shall be completed in optic termination panels with splicing trays as indicated on the Contract Drawings, and per approved splicing procedure.

B. Supply materials required for fiber optic splicing, including but not limited to:
   1. De-Natured Alcohol.
   2. Fusion Splice Protection Sleeve.
   3. Velcro cable ties.
   4. Labels.
   5. Sealing Tape.

C. Splicing shall be completed using fusion-splicing equipment. Protect individual splices with a reinforced heat shrink sleeve affixed to splice tray.

D. Splice Trays: Firmly mount into outdoor rated splice enclosure or into cabinet mounted splice enclosure as shown on Contract Drawings.

E. Minimum 2 feet (610 mm) of bare fiber shall be coiled and stored in the splice tray in a protected manner. Plastic Cable ties may not be utilized to directly secure exposed bare fiber.

F. Minimum 3 feet (914 mm) of each buffer tube in the fiber optic cable shall be coiled and stored in the splice enclosure or distribution panel.

G. Properly fasten cables to prevent against pulling out of the splice enclosure or distribution panel. The fiber cable central strength member shall be attached to the FDP, the outer jacket of the cable shall be attached to the FDP with a cable clamp. All securing hardware shall be in accordance with FDP manufactured supplied kits and instruction.

H. All fiber optic splices shall be fusion splices. Splices shall be stored within FDP or Splice Case splice trays for the purpose of passing optical connections to FDP pre-connectorized pigtail assemblies, or to an additional OSP fiber cable.

I. Fusion splicing shall be performed by qualified personnel utilizing a splicer equipped with Local Injection Detection (LID) to optimize splices. Maximum Splice Loss Attenuation: max 0.1dB at 1310, 1550, and 1625nm.

J. Fusion Splicing equipment shall be capable of working on battery power. Provide spare battery units when no local power source is available.

K. Terminate fibers with factory polished pre-connectorized pigtaills.

L. Location: Splicing shall be within Fiber Distribution Panels, and Splice Case Enclosures.

M. Fusions splice pigtaills shall be labeled with the fiber number using a pre-printed vinyl number tag.
N. Splice trays shall be labeled including fibers spliced in the tray. Cables at each location shall be designated with the next termination point at the other end of the cable.

O. Design and maintain splice trays as re-enterable.

P. Loop-through splicing shall be used at locations as shown on contract drawings in lieu of dedicated cables to a served location. In loop-through splicing, only the fiber strands branching off from the main cable to enter a communication room site are cut and spliced. The other fibers are not cut. The jacket is cut from the cable exposing the buffer tubes, fibers being “dropped” are cut and spliced, the remaining fibers are carefully dressed within the splice case (not cut) and continue out of splice case.

Q. For fiber optic cables that are the 900um tight buffered designed specifically for direct field connectorizing, install field connectors in accordance with manufacture instruction, utilizing manufacture supplied tools. Prior to field installation. Demonstrate to Resident Engineer for approval, proper installation of field installable type fiber connectors.

R. Notify the Resident Engineer in writing at least 2 weeks in advance of terminating each section of optical cable.

3.05 CABLE IDENTIFICATION

A. Tag cables at the following locations:
   1. Termination points.
   2. Fiber Distribution Panels.
   3. Where cable enters or exits communication rooms or houses, TPSS, signal rooms/houses, manholes, handholds, and housings.
   4. On each side of barriers the cable passes through.
   5. At aerial exits from conduit risers.
   6. Innerducts within handholes/manholes that contain cables shall be tagged with listing of cables are within.

3.06 FIELD TESTING-GENERAL

A. Demonstrate the functionality of the installed system through testing as specified bellow and in accordance with Section 01 95 00, System Testing and Integration.

B. Tests shall be conducted in accordance with an approved test plan that shall cover the key functional requirements of the Work.

C. Provide suitable test equipment, instruments and labor for the purpose of tests.

D. Test shall be performed after installation is complete.

E. Provide sufficient notice of not less than 5 Working Days prior to the commencement of testing. Submit with this notice a schedule of all tests covered by this notice. A Resident Engineer representative shall be invited to witness each field testing event.

F. Optical Attenuation and OTDR testing shall be recorded: from FDP to FDP (both Inter and Intra station), and for Radio Cabinet fiber cable connector link between stations.

G. All Attenuation and OTDR testing shall be done bi-directionally on each strand. For Fiber Cable strands that are dedicated for future terminations as part of Link expansion,
temporary fiber pigtail connectors shall be spliced to bare strands as required for the purpose of bi-directional testing. Transmit and receive launch cables shall be utilized.

H. All fiber optic strands shall be tested in accordance with the field tests specifications defined by the TIA/EIA-568-B.1-2, TIA-568-C.2 and FOA testing procedures and shall utilize transmit and receive launch cables.

I. TIA/EIA-568-B.1-2, shall be used to define the passive cabling network, to include cable, connectors, and splices (if present), between two Fiber Distribution Panels (connecting hardware). This TIA/EIA document shall be used to describe all applicable link segments.

J. All of fiber cabling links installed shall be tested and shall pass the requirements of the standards mentioned above, including patch cords after they have been installed between equipment and FDP. Any failing links shall be diagnosed and corrected prior to system acceptance. The corrective action shall be followed with a new test to prove that the corrected link meets the performance requirements. Final passing results of tests for all links shall be provided in the test results documentation. All terminations will be cleaned and inspected with an electronic microscope and a soft and hard copy kept and presented with the testing results.

K. Fiber optic technicians shall be qualified and have obtained a certificate, as proof thereof to execute all fiber optic testing. Certificates may have been issued by any of the following organizations or an equivalent organization.

1. The manufacture of the fiber optic cable or connectors.
2. The manufacture of the test equipment used for the field certification.
3. Training organizations authorized by BICSI (Building Industry Consulting Services International).

L. Field test instruments for single mode fiber cabling shall meet the requirements of TIA/EIA-526-7A-B and TIA-568-C

M. Test instrument calibration date shall be within the calibration period recommended by the vendor in order to achieve the vendor specified measurement accuracy.

N. Fiber optic test launch cables and adaptors shall be of high quality and the cables not show excessive wear resulting from repetitive coiling and storing of the test instrument interface adaptors.

O. Prior to testing, all fiber optic connectors and bare fiber ends are to be properly cleaned using a residue free alcohol solution (better than 91 percent de-natured alcohol and distilled water) and compressed air.

P. The pass or fail condition for the link under test is determined by the results of the required individual tests.

Q. A pass or fail result for each parameter is determined by comparing the measured values with the specified test limits for that parameter.

R. All field testing requires signature of an independent witness approved by Resident Engineer.

3.07 FIELD INSTALLATION TESTING

A. Pre-Installation Testing.
1. Pre-installation tests shall be conducted on the cable reels after shipment to but prior to installation. These tests shall be performed in accordance with TIA/EIA-455-B.

2. Verify fiber strand continuity and cable length for fiber cables on shipment reel, verify cable length with printed footage marking on cable jacket. Verify Buffer tube construction and fiber strand count.

3. Provide OTDR trace at 1550 nm, with both soft trace file, and hardcopy record for each fiber strand including the electron microscope files.

B. Fiber Cable Plant Testing - Attenuation Loss.

1. In compliance to TIA/EIA-568, the performance parameter for field testing of fiber optic links shall be link attenuation (insertion loss).

2. Link attenuation shall be calculated by the following formulas as specified in ANSI/TIA/EIA-568:

   a. Link Attenuation = Cable Attenuation + Connector Attenuation + Splice Attenuation.

   b. Cable Attenuation (dB) = Attenuation Coefficient (dB/km) x Length (km).

   c. Connector Attenuation (dB) = number of connector pairs x connector loss (dB). Maximum allowable connector loss = 0.75 dB.

   d. Splice Attenuation (dB) = number of splices (S) x Splice loss (dB). Maximum allowable splice loss = 0.2 dB.

   e. The maximum values for the Attenuation Coefficient are listed below:

      1) Single mode fiber cable (outside plant), 1310 nm: 0.5 dB/km.
      2) Single mode fiber cable (outside plant), 1550 nm: 0.5 dB/km.

   f. Link attenuation shall not include any active devices or passive devices other than cable, connectors, and splices.

   g. Test equipment that measures the link length and automatically calculates the link loss based on the above formulas is preferred.

3. In the above link test parameters, attenuation is based on the use of the Two Reference Jumper Method specified by TIA/EIA-526-7, or the equivalent method. The tester shall follow the procedures established by these standards or application notes to ensure accuracy of test results.

4. Single-mode fiber links shall be tested at 1310 nm and 1550 nm in accordance with TIA/EIA-526-7, Method utilizing Two Reference Jumpers or the equivalent method. Single-mode links shall be certified with test tools using laser light sources at 1310 nm and 1550 nm.

C. Fiber Cable Plant - (OTDR) Testing.

1. Fiber Optic Testing utilizing an Optical Time Domain Reflectometer (OTDR) shall adhere to the following specifications: TIA/EIA 455-78,TIA/EIA 455-133.

2. OTDR Acceptance Testing: Fiber Links and Splices:
a. OTDR testing to be completed on each section of the fiber network after splicing is completed.

b. A fiber link shall be defined as a continuous section of fiber from connector to connector that may pass through a number of intermediate splices.

c. Test each fiber link in the cable at 1310 nm and 1550 nm (for single-mode) operating wavelengths for anomalies and to ensure uniformity of cable attenuation and connector insertion loss.

d. Use a dedicated “launch-cable” patch cord of sufficient length to ensure that start of the fiber under test is not in the “dead zone” of the OTDR. The first connector of the link under test shall be visible on the trace.

e. Optical Return Loss (ORL) for each link shall be measured.

f. Fiber link length shall be measured.

g. Test Results:
   1) Reflective events shall not exceed minus 40 dB.
   2) Connections shall not exceed 0.75 dB of attenuation.
   3) Non-reflective events (splices) shall not exceed 0.2 dB (bi-directional average). Fusion splice losses in excess of 0.2 dB requirement shall be re-spliced and re-tested until compliant at the contractors expense. Deviations from maximum splice loss may be approved by Resident Engineer on a per splice basis.
   4) Point discontinuities shall not exceed 0.1 dB.
   5) ORL shall be less than minus 30 dB.

h. OTDR Test results shall include OTDR link and channel traces and event tables at the required wavelengths, and the length for each optical fiber as calculated by the OTDR.

3.08 FIELD SYSTEM TESTING - FIBER SPAN CHARACTERIZATION

A. General Requirements.
   1. Perform fiber optic Characterization testing on 10GigE and GigE Inter-station fiber strand links.
   2. For traffic carrying 10GigE or GigE Links, Fiber Characterization Testing shall be from equipment node patch cord to equipment node patch cord and include all intermediary FDP fiber patch cross-connections that make up the full optical path of the link under test.
   3. These Fiber Characterization Tests are in addition to the General Fiber cable strand testing required for fiber cable strands (active and dark)
   4. Fiber characterization is defined as a series of tests taken on a fiber optic span to determine the integrity of the fiber, installed practices, and performance for a desired transmission rate (1Gb/s or faster) and or Service to be implemented (DWDM). Fiber Qualification tests:
a. Optical Return Loss (ORL): 1550nm wavelength from both fiber ends.
b. Optical Loss Test Set (OLTS): End to end Insertion Loss at 1550nm & 1625nm wavelengths, bi-directionally averaged.
c. OTDR: 1550nm & 1625nm wavelengths, bi-directionally averaged.
d. Polarization Mode Dispersion (PMD): 1550nm wavelength, single ended.
e. Chromatic Dispersion (CD): 1520nm to 1630nm at 10nm wavelength increments, single ended. Test instrument shall save the results in memory and to supply a hard and soft copy.

B. ORL and Optical Loss Test Parameters.
   1. Required fiber spans shall be tested with optical power meter and light source combination. ORL measurements shall be conducted at 1550nm only. The loss results shall be conducted at 1550nm and 1625nm and include measurements for:
      a. ORL results from A to B and B to A.
      b. Actual loss of the fiber span under test from A to B and B to A.
      c. Average bi-directional loss of the fiber span under test.
   2. All loss readings shall be within calculated loss budget for link under test. Exceptions shall be communicated to Resident Engineer prior to leaving test location. Fiber test contractor to recommend corrective action that will resolve any span test exceptions prior to use by network equipment. ORL and Optical loss reports to be submitted as part of final report to Resident Engineer for approval.

C. OTDR Test Parameters.
   1. Required fiber spans shall be tested with an OTDR. The OTDR tests shall be conducted at 1550nm and 1625nm and include measurements for:
      a. Total end to end average loss (bi-directionally) of fiber under test.
      b. Total length of fiber span under test.
      c. Average loss (bi-directionally averaged) of each splice in the fiber span under test.
      d. Reflectance and average loss of each connector in the fiber span under test.
   2. Bi-directional OTDR reports shall be generated with the OTDR manufacture’s software. Fiber spans shall meet calculated test threshold criteria. Exceptions shall be communicated to Resident Engineer prior to leaving test location. Recommend corrective action that will resolve any span test exceptions prior to being used by network equipment. OTDR test reports, including raw trace files to be submitted as part of final report to Resident Engineer for approval.

D. Dispersion Test Parameters (PMD and CD).
   1. Polarization Mode Dispersion (PMD) results shall be conducted at 1550nm (broadBand) and include:
a. PMD results for fiber span under test (in ps).
b. PMD coefficient result for the fiber under test (in ps/√km).
c. Pass / Fail indication for the fiber under test.

2. Chromatic Dispersion (CD) measurement tests are conducted across the spectral range from 1520nm to 1630nm at 10nm increments. Include results for:
   a. Zero dispersion point for fiber under test (in nm).
   b. Dispersion at wavelengths to be transmitted (in ps/nm).
   c. Dispersion normalized to the length of the fiber span under test (in ps/nm-Km).

3. PMD and CD results to be generated by equipment manufacture software. Test results shall be span thresholds per Link bit rate speeds. Fiber test contractor to recommend corrective action that will resolve any span test exceptions prior to use by network equipment. PMD/CD test reports to be submitted as part of final report to Resident Engineer for approval.

E. Fiber Characterization Test Acceptance Criteria.

1. Attenuation Threshold.

<table>
<thead>
<tr>
<th>Splice/Connector Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Splice Loss (bi-directional) (ea) (max)</td>
</tr>
<tr>
<td>Connector Loss (ea) (max)</td>
</tr>
</tbody>
</table>
| Connector Reflection | UPC: -50dB
| | APC: -55dB |

<table>
<thead>
<tr>
<th>Fiber Attenuation Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attenuation (dB/Km)</strong></td>
</tr>
<tr>
<td><strong>1550 nm</strong></td>
</tr>
<tr>
<td>0.25</td>
</tr>
</tbody>
</table>

Max loss budgets (in dB) will be determined by:
(Length in km * 0.25)+(#connector pairs * 0.5)+(#splices * 0.2@1550nm)

2. ORL Threshold: ORL results will be 27dB or greater for both 1550 nm and 1625 nm

3. PMD Threshold: Based on industry standards and are specific to the transmission rate of the network system.

<table>
<thead>
<tr>
<th>PMD Thresholds</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bit Rate</strong></td>
</tr>
<tr>
<td>2.5 Gb/s</td>
</tr>
<tr>
<td>10 Gb/s</td>
</tr>
<tr>
<td>40 Gb/s</td>
</tr>
</tbody>
</table>

4. CD Threshold: Based on industry standards and are specific to the transmission rate of the network system.
5. Fiber Characterization Test Results.
   a. Test procedures and results shall be documented precisely and complete reports shall be provided to the satisfaction of the Resident Engineer.
   b. Based on field test results, a detailed fiber span analysis report with recommendations identifying the transmission capabilities shall be generated. Links under test shall support the GigE or higher transmission speeds suitable for MPLS Network backbone links.
   c. Submittals shall include, but are not limited to, test plans and procedures, pass/fail criteria for each link, the forms for recording of test and test results including test witness signature areas, results analysis and recommendations. Submittals shall be organized with all tests performed on a specific cable submitted at one time, not as separate submittals.

3.09 CABLE PLANT TEST RESULT DOCUMENTATION

A. The test result information for each link shall be recorded in the memory of the field test equipment upon completion of the test.

B. The test result records saved by the test instrument shall be transferred into a Windows-based database utility that allows for the maintenance, inspection and archiving of these tests records. Test results shall be transfer to the PC unaltered.

C. Test results shall be turned over to the test witness at the end of each testing work shift. The fiber testing technician shall provide the stored OTDR trace files of the fibers under test via a USB output port for transfer to a portable USB flash thumb drive. The OTDR trace file results shall be in an electronic format to allow Resident Engineer to view the trace files utilizing standard OTDR trace file viewer software.

D. OTDR traces shall be recorded in suitable electronic format. OTDR vendor approved software tools and applicable licenses required to view, inspect, sort, and print the OTDR traces shall be provided to Resident Engineer at least 30 days prior to start of OTDR testing at no additional charge.

E. Expand the vertical and horizontal scales used on the OTDR to maximize the amount of detail shown on the OTDR trace, even if these parameters can be adjusted later using display software.

F. Ensure that traces identify the end points of the fiber under test and the fiber designation. If this information is not provided by the trace itself, provide a cross-reference table between the stored trace file name and the fiber designation.

G. A paper copy of the test results shall be provided that lists the links that have been tested with the following summary information:

<table>
<thead>
<tr>
<th>Bit Rate</th>
<th>CD (Delay)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 Gb/s</td>
<td>16640 ps/nm</td>
</tr>
<tr>
<td>10 Gb/s</td>
<td>1040 ps/nm</td>
</tr>
<tr>
<td>40 Gb/s</td>
<td>65 ps/nm</td>
</tr>
</tbody>
</table>
1. The Identification of the link in accordance with the optical fiber cable naming convention defined in the overall system documentation.

2. The overall Pass/Fail evaluation of the link under test including the attenuation worst-case margin (margin is defined as the difference between the measured value and the test limit value).

3. The date and time the test results were saved to the test equipment memory.

4. All cable Test results shall be grouped by cable identification name/number for each cable as one submittal of that particular cable test results.

H. General information shall be provided in the electronic database containing the fiber test result information for each link:

1. Identification of the site.

2. Overall Pass/Fail evaluation of the link under test.

3. Name of the standard selected to execute the stored test results.

4. Fiber cable type and the value of the ‘index of refraction’ used for length calculations.

5. Date and time the test results were saved to the test equipment memory.

6. Model, serial number, and calibration date of the optical test equipment.

7. Revision of the tester software and the revision of the test standards database within the tester.

I. Provide detail test results data in the electronic database for each tested optical fiber shall contain the following information:

1. Identification of the link/fiber in accordance with the naming convention defined in the overall system documentation.

2. Insertion loss (attenuation) measured at each wavelength, the test limit calculated for the corresponding wavelength and margin (difference between the measured attenuation and the test limit value).

3. Link length shall be reported for each optical fiber for which the test limit was calculated based on the formulas specified herein under Fiber Cable Plant Performance Testing Parameters.

3.10 FIBER OPTIC SYSTEM LABELING

A. Fiber Optic Cable

1. Fiber Optic cable shall be identified/labeled whenever entering and exiting a splice enclosure, manhole/hatch, cabinet, FDP, pull point/box/hatch, and at all FDP terminals.

2. Label fiber cable strand counts that are in each splice tray by affixing a permanent label to surface of splice tray cover.

3. Permanent marking tags fastened securely to the cables shall be used for identification.
4. Cable designation shall consistently conform to the overall scheme approved by Sound Transit to indicate location, circuit, device, cable number, node, port position etc.

5. Letters and numbers shall be used. Identification shall be made with a clear, machine produced, indelible marking.

B. Innerduct

1. Innerduct shall be labeled at each end and where it is passed through a vault as “ccc - iii”, where ‘ccc’ is the conduit number from the site as-built drawings and ‘iii’ is the innerduct number, within the conduit.

C. Fiber Distribution Termination Panels

1. Label each termination panel at each termination point for each fiber.

2. Termination labels shall conform to the overall scheme approved by Sound Transit to indicate location, device and next access point.

3. Identification shall be made with a clear, machine produced, indelible marking.

3.11 FINAL INSPECTION

A. Final Inspection will include the following activities:

1. ‘As-built’ drawings and manuals will be examined by Sound Transit for conformance to the Drawings, Codes, Regulations, and General Accuracy. Any variation from specifications will be highlighted.

2. Test results will be reviewed, both electronic and paper copies. Verify supplied fiber cable test database results is complete for cables tested as part of contract.

3. Work will be physically inspected to ensure that work has been completed in accordance with the specifications.

4. Upon completion of final inspection activities, any deficiencies will be recorded. Deficiencies shall be corrected by the appropriate party and will be re-inspected by the Resident Engineer.

5. Final Inspection shall not be deemed complete until deficiencies are corrected.

3.12 SYSTEM SUPPORT

A. Maintenance

1. Develop a maintenance plan that details preventative maintenance, outage repair, and administration procedures required for systems optical fiber equipment prior to acceptance.

2. List personnel, equipment, and duration required for each procedure developed. Include frequency necessary for preventative maintenance procedures.

B. System Documentation and Record Drawings

1. As-Built Documents. Provide the following documents as part of the as-built set:
   a. Cable Plant Test Results documentation in accordance with the above specifications.
b. Optical fiber cable plant schedule including: Cable ID, cable length, conduit/duct bank installation location, splice locations, fiber distribution panel port and tray terminations locations, patch cord routing.

c. Drawings: Fiber Plant schematic, Riser diagram, Point to Point fiber strand termination details, Fiber Distribution Panel details.

d. Final Equipment BOM lists.

END OF SECTION
SECTION 27 15 02
COMMUNICATIONS CONDUCTORS AND CABLES

PART 1 - GENERAL

1.01 WORK INCLUDED

A. Provide all labor, materials, tools, and equipment required for the complete installation of all Communications Conductors and Cables called for in the Contract Documents.

B. In order to conform to the overall project event schedule, the contractor shall survey the work areas and coordinate conductor and cabling installation with other applicable trades.

1.02 SUMMARY

A. This section includes the minimum requirements for Communications Conductors and Cables.

B. Communications conductors and cables shall consist of 120VAC power and control wiring, grounding conductors, audio speaker wiring, 24 VDC wiring and analog signal wiring for BMS, EVS, PBX, Door Access, Voice, PA, VMS and CCTV systems including digital and analog devices.

C. Audio/Public Address circuits installed in environments where electromagnetic compatibility (EMC) can be accomplished through BICSI TDMM and TIA/EIA-569-C compliant separation from sources of electromagnetic interference (EMI) shall utilize unshielded cable.

D. Audio/Public Address circuits installed in environments where electromagnetic compatibility (EMC) cannot be accomplished through BICSI TDMM and TIA/EIA-569-C compliant separation from sources of electromagnetic interference (EMI) shall utilize shielded cable.

1.03 REFERENCES

A. American Society of Mechanical Engineers (ASME)
   1. ASME Nuclear Quality Assurance (NQA-1)

B. Building Industry Consulting Service International (BISCI)
   1. BICSI Information Technology Systems Installation Methods Manual (ITSIMM), 7th Edition
   2. BICSI Telecommunications Distribution Methods Manual (TDMM), 13th Edition

C. Code of Federal Regulations (CFR)
   1. 10 CFR 50, Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

D. Institute of Electrical and Electronics Engineers (IEEE)
   1. IEEE 1202 Standard for Flame-Propagation Testing of Wire and Cable
E. International Organization for Standards (ISO)
   1. ISO 9001 Quality Management Systems

F. National Fire Protection Association (NFPA)
   2. NFPA 72 National Fire Alarm and Signaling Code
   3. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems
   4. NFPA 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Space

G. Telecommunications Industry Association Electronic Industries Alliance (TIA/EIA)
   1. TIA/EIA-568-C Generic Telecommunications Cabling for Customer Premises
   2. TIA/EIA-569-C Commercial Building Standard for Telecommunications Pathways and Spaces

H. Underwriters Laboratories (UL)
   1. UL 444 Standard for Safety Communications Cables
   2. UL 969 Standard for Marking and Labeling Systems
   3. UL 1685 Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables
   4. UL 2196 Standard for Fire Test for Circuit Integrity of Fire-Resistive Power, Instrumentation, Control, and Data Cables

1.04 SUBMITTALS

A. Drawings
   1. The initial drawing list shall contain all anticipated copper Communications Cabling System drawings that will be created as part of this Contract. Standard manufacturer drawings that are generally provided with the product or subsystem need not be included in the drawing list.
   2. All drawings shall identify conductor and cable types, gauge number, and shielding-ground connections
   3. All conductors, cables, equipment and communications devices shall be named and labeled with Sound Transit’s Light Rail Equipment and Facilities Numbering Plan.
   4. Each subsequent submittal after the preliminary design shall refine and update the drawing list.
   5. The final as-built drawing list shall contain all Communications Conductors and Cables created specifically for this Contract.

B. Test Plans
1. Pre-testing of materials test plan, and results document.
2. Cable Installation plan, and installation inspection results document.
3. Field installation testing plan and results.

C. Product Specification Sheets

D. Design Reviews
   1. Preliminary design review
   2. Final design review

E. Bill of Materials

F. Preliminary Design Document:
   1. Show with block diagrams the function and geographic layout of the facility or station communications conductor and cable connections to all devices, to include:
      a. Assessment of suitability for design of duct bank, inner ducts, conduits, and general site conditions for the installation of cables and equipment.
      b. Duct bank and inner duct/conduit occupancy drawings.
      c. Duct/conduit plan drawings with distance indications on the riser diagrams.
      d. Duct and conduits with communications conductor and cable runs shall comply with all applicable NFPA 130 requirements for pathway survivability and redundancy.
      e. All conductors and cables shall be listed in a table in the design document(s).
      f. Spare communications wiring capacity planned to be left over, after handwork of the facility/station.
      g. All termination connectors shall be noted for type, brand and model, on the drawings and tables.
      h. All communications network connections shall be noted in the Cables design document(s) for signal type running over the wire such as, RS-232, RS-422, RS-485, ModBus, Profibus, etc., on the drawings and tables.
      i. All conductors and cables shall have the terminations noted for grounding or not, both in the drawings and tables.
      j. A grounding hierarchical structure shall be shown in a dedicated drawing, from remote devices back to Communications Rooms and back to main facility or station ground. Special attention shall be paid to proper ground isolation.

G. Design Documents.
   1. Technical Data Sheets - Submit complete technical data sheets for the conductors, cables and ancillary equipment proposed. Demonstrate compliance with mechanical and electrical properties specified herein.
2. Manufacturer Experience - Submit information for each proposed manufacturer including experience in manufacturing conductors, cable, and termination equipment for rapid transit and railroad applications and quality assurance program and warranty.

3. Contractor Experience - Submit information for contractor staff including experience in installation and termination of twisted pair communications cable for rapid transit and railroad applications and quality assurance program and warranty.

4. Conductors and Cable Lists, Plans and Drawings - Submit conductors and cable system schematic, plan, and detail drawings, indicating complete conductor and cable system with device and equipment names at each end. Note equipment placement within station and cross-passages. Include profiles showing location of cabinets/racks, rack elevation drawings, including all cable termination details. Specify cable labeling in accordance with Sound Transit existing standards.

5. Material/Equipment/Assembly/Installation Details - Submittal shall include materials, equipment, assembly and installation required to carry out functions and purposes indicated in these Specifications, and to make the system suitable for the purpose for which it is intended, whether or not such materials, equipment, assembly and installation are specially indicated in the requirements of these Specifications.

6. Termination Instructions - Submit approved termination connectors.

H. Communications Conductor and Cable Installation/Pull Plan.

1. Submit Installation plan as outlined herein.

I. Testing Documents.

1. Submit documents in accordance with 01 95 00 System Testing and Integration.
2. Test procedures for each test
3. Test results for each test a maximum of 10 days after date test was performed
4. Factory Production Test:
   a. Submit Certified Test Report prior to shipment of cables.
5. Pre-Installation Reel Test: Submit Communications Cable Reel Test Report after shipment, but prior to installation.
6. Field Test Report, including the following:
   a. Continuity test
   b. Insulation resistance test
   c. Cable insulation tests

J. Spare parts

1. Provide spare cable remaining on reels.
2. Provide spare termination connectors.
1.05 QUALITY ASSURANCE/QUALITY CONTROL (CABLE MANUFACTURER)

A. Cable shall be manufactured and tested under the control of a Quality Assurance program that meets the requirements of 10 CFR 50, Appendix B, as elaborated in ASME NQA-1, for materials traceability only.

B. Conductor and Cable Manufacturer: Manufacturer shall have a performance record demonstrating a minimum of 30 years successful operating experience in transit, utility or industrial power applications for the insulation compound and conductor assemblies provided.

1. Quality Assurance Program: Cable manufacturers, in accordance with requirements of these Specifications, are required to have in place or implement, an effective quality assurance program adhering to the requirements of ISO 9001 to ensure purchase control performance.

2. Sample Specimens: If requested, furnish Resident Engineer sample specimens in 4 foot lengths identical to proposed cable including connectors and peripherals. Sample specimens shall remain property of Sound Transit.

1.06 QUALITY ASSURANCE (QUALIFIED COMMUNICATIONS CABLE DESIGN, INSTALLATION AND TERMINATION PERSONNEL)

A. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.

B. Communications Network Terminations: Trained technicians who have successfully attended an appropriate training program and have obtained a certificate as proof thereof shall perform the terminations. Sound Transit may request a copy of the certificates. These certificates may have been issued by any of the following organizations or an equivalent organization:

1. Manufacturer of the connectors or cable.

2. Training organizations (e.g., BICSI, A Telecommunications Association headquarters in Tampa, Florida; ACP [Association of Cabling Professionals™] Cabling Business Institute located in Dallas, Texas)

1.07 DELIVERY, STORAGE, AND HANDLING

A. Packing

1. Ship cable on non-returnable wooden or plastic reels.

2. Drum Diameter: Minimum 20 times the diameter of cable.

3. Reels: Substantial enough to withstand reasonable handling, designed with inner end of accessible but protected from injury.

4. Cable Ends: Sealed to prevent entrance of moisture and securely fastened to prevent ends from becoming loose during transit.

B. Marking

1. Mark each reel on outside flange with the following information:

   a. Manufacturer’s name.

   b. Contract name and number.

   c. Cable identification number.
d. Cable length.
e. Date of manufacture.

C. Delivery
1. Inspect cables at time of delivery at construction site to assure no damage was done during shipping.
2. Inspect every reel for physical damage.
3. Submit to Resident Engineer cable reel inspection report.
4. Replace any damaged or rejected cable promptly.

D. Storage
1. Store cables on solid surfaces designed to support cable reels which drain adequately and do not allow accumulation of liquids, oils, or chemicals.
2. Cables shall be protected from wetting by rain or snow, or any other sources of unintended water.
3. Align and protect cable reels so as not to allow reel flanges to damage other reels.
4. Provide adequate aisles and barricades to allow accessibility and to prevent construction equipment from damaging cable reels.
5. Reseal cable ends promptly when a length is cut from reel.

E. Handling
1. Handle cable reels using a sling and spreader attached to a shaft through the reel hubs, or by cradling both flanges between lift truck forks.
2. Do not lift reels by top reel flange or drop from any height.
3. Ensure lift truck forks do not touch cable surfaces on reel.
4. Roll reels in the direction opposite the cable wind on reel.
5. Do not lay reels flat.

PART 2 - PRODUCTS

2.01 CONDUCTORS

A. 120 VAC Power and Control Wiring: Single conductor, stranded, soft annealed copper conductors with 600 V cross linked polyethylene insulation type XHHW-2. Wire smaller than 14 AWG shall not be used unless specifically called for on drawings.

B. Safety Ground wire, green plastic insulated, soft annealed copper conductors with 600 V cross linked polyethylene insulation type XHHW-2, 14 AWG, connecting the grounding tree from the Communications Rooms to the endpoint devices.

2.02 CABLING - GENERAL

A. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 (Article 800) for Communications, Multipurpose Plenum Rated:
Type CMP complying with NFPA 262 (smoke and flame propagation testing) or permitted substitute as defined by the NEC complying with UL 1685 (low smoke) and FT4/IEEE 1202 (flame propagation) testing.

B. Cable outer jacketing to be rated for wet locations and operating temperature -20 deg. C to +90 deg. C.

C. Cables shall be marked as NRTL verified.

D. Voltage Rating: 300V

E. Fire Resistivity: When required by AHJ per NFPA 130 cable to be 2-hour fire rated complying with UL 2196.

2.03 CABLES

A. UNSHIELDED AUDIO CABLE (TYPE 1)

1. Description: Twisted pair 12 AWG minimum stranded bare copper polyolefin insulated conductors covered with a UV resistant jacket, in color readily available from manufacturer, typically gray.

2. The cable shall not incorporate an overall shield.

B. SHIELDED AUDIO CABLE (TYPE 2)

1. Description: Twisted pair 12 AWG minimum stranded bare copper polyolefin insulated conductors covered with a UV resistant jacket, in color readily available from manufacturer, typically gray.

2. The cable shall incorporate an overall helical or longitudinal plastic and metal laminated tape foil shield with 20 AWG minimum drain wire in contact with metal side of tape.

C. 24 V SHIELDED TWISTED PAIR CABLE (TYPE 3)

1. Description: Twisted pair 18 AWG, stranded copper polyolefin insulated conductors covered with a UV resistant jacket, in color readily available from manufacturer, typically black.

2. The cable shall incorporate an overall helical or longitudinal plastic and metal laminated tape foil shield with 20 AWG minimum drain wire in contact with metal side of tape.

D. ANALOG SIGNAL WIRING SHIELDED MULTIPLE TWISTED PAIR CABLE (TYPE 4)

1. Description: Two (2) or more multiple twisted pairs 18 AWG, stranded copper polyolefin insulated conductors covered with a UV resistant jacket, in color readily available from manufacturer, typically black.

2. The cable shall incorporate an overall helical or longitudinal plastic and metal laminated tape foil shield with 20 AWG minimum drain wire in contact with metal side of tape.

2.04 TRAY CABLES

1. Cables installed in trays shall be TC rated for such application. The cables shall be installed in accordance with the requirements of NFPA 70 (Article 396).
2. All cables traversing more than 50 feet in a room not installed in an enclosed raceway shall be of low smoke zero halogen (LSZH) construction.

2.05 TERMINATIONS

A. Terminate wiring entering and leaving enclosures on a numbered terminal strip.

B. Arrange wiring for vertical conduit entry. Terminal blocks shall have no more than two wires connected per termination point. Factory jumpers may be used where required.

C. Provide 25 percent spare in each enclosure of each type termination.

D. Terminal Blocks

1. Manufacturer: Wago, or approved equal.

2. Incoming and outgoing wiring to the panel shall be landed on DIN rail mounted, finger safe terminal blocks.

3. I/O wiring terminal blocks shall accept between #28 to #12 AWG wire. Select different colors to distinguish inputs and outputs.

4. Analog input circuits shall be landed on fused terminal blocks with indicating lamp for blown fuse. Include appropriate fuses rated to protect PLC inputs.

5. Terminal blocks shall be screw-type. Spring clamping mechanism terminal blocks shall not be accepted.

6. Number terminals with a permanent, nonconductive strip on each block according to detailed wiring drawings to be provided by the Contractor.

7. Provide supervised terminations to detect open circuits for all wiring associated with the fire-life safety system.

8. Terminal Strip Colors (not wire colors):

   a. Digital Input Points: Beige
   b. Digital Output Points: Brown
   c. Analog Input Points: Purple
   d. Analog Output Points: Yellow
   e. Power Supply (120 VAC or less): Black (hot), Gray (neutral)
   f. Any voltage greater than 120 VAC: Orange (hot), Gray (neutral)
   g. Network: Red/Orange
   h. Grounds: Green
   i. Other Terminal Connections: Beige

2.06 CABLE TRAY

A. Provide cable tray in accordance with Section 26 05 33, Raceway and Boxes for Electrical Systems.

B. Communications room cable tray size: 24 inches width; 6 inches depth
C. Communications room cable tray to be of the ladder type with 6 inches rung spacing.

2.07 IDENTIFICATION TAGS

A. Material: Plastic, heat-shrinkable radiation cross-linked, thermally stabilized, flame-retarded modified polyolefin sleeves.

B. Label: List device or terminal block destination and origin, and cable number.

C. Comply with TIA/EIA-606-A and UL 969 for labeling materials, including label stocks, laminating adhesives, and inks used by label printers.

D. Sleeves: Smear resistant prior to shrinking, achieve mark permanency when shrunk without the need for permatizing equipment, or when standard ballpoint pens or high-carbon content fabric ribbons are used.

E. Chemical Resistance: Resistant to common industrial fluids including but not limited to; Freon TF, isopropyl alcohol, and Ethylene Glycol.

PART 3 - EXECUTION

3.01 INSTALLATION PLAN

A. Develop a written cable installation procedure and check-off list for approval prior to cable installation in accordance with TIA/EIA 568-C and TIA/EIA-569-C.

B. Submit information for each segment of cable to be installed.

C. Provide pulling layout including distances and tension calculations, for each cable pull.

D. Provide pulling equipment and tension monitoring devices.

E. Provide chronological plan for installing cable, including estimated time for each pull and plan for protecting cable on-reel and in slack loops during installation.

F. Installation plan shall be based on Contractor’s review of the conduit plans, and field site survey.

G. Include a cable plan and installation information for each cable pull.

H. Verify conduit size, conduit fill, conduit bend radii, manhole spacing, manhole size, raceways, ducts and associated hardware are proper prior to the intended installation.

I. Verify required cable length for each cable run prior to installation. Civil stationing appearing on referenced drawings may be used for defining locations and estimating cable lengths. Do not use existing drawings to determine final lengths and cuts. Determine actual lengths by making on-site inspections and measurements.

J. Include manufacture approved procedures for feeding cable into conduit, to maintain proper bend radii and minimize friction.

3.02 INSTALLATION

A. Install all conductors and cables in accordance with BICSI ITSIMM standards and as shown on installation drawings.

B. Material and workmanship shall be of the highest quality assuring durability for minimum life expectancy of 40 years.
C. Replace all cables damaged during installation.
D. No low voltage wire or cable shall be installed in the same conduit or cable tray with light, power, or Class 1 signal wiring.
E. Power, control and Class I wiring entering racks, control panels or devices shall be isolated from low voltage wire and cable by means of a physical barrier or in a slotted wall wire duct separate from the Class 2 and 3 wiring system.
F. Wires and cables shall be continuous without splices between junction boxes, terminals, pull boxes, manholes and hand holes.
G. Bend Radius: Minimum 10 times the diameter of the cable or manufacturers' recommended minimum bending radius, but not less than the radii specified in the BICSI ITSIMM “Cabling Terminations Practices” chapter.
H. Notify Resident Engineer 48 hours prior to installing cables.
I. Install cable in accordance with submitted, and Sound Transit approved, installation plan, and with service loop excess at ends of cable for maintenance and free movement of attached communications equipment.
J. Provide installation hardware to route, support, terminate, and protect cable installation.
K. Provide conduit to connect Sound Transit furnished raceways to equipment, enclosures, and devices.
L. Use lubrication when pulling cables into conduit, pipe, or duct bank.
M. Pulling cable: Comply with BICSI ITSIMM Chapter 4 “Pulling Cable”. Monitor cable pulling tensions.
N. Sealing
   1. Seal cable entrance openings in equipment enclosures, rooms, and junction boxes with either a compression type fitting or pliable sealing compound after the cable is in place.
   2. Use sealing compound seal area around cable where cable emerges from conduit, pipe or duct bank.
   3. Sealing in accordance with NFPA 130 where required.
O. Installation in Conduit or Pipe
   1. Inspect, mandrel, swab, and clean conduits and ensure a clean, smooth, concentric interior surface prior to cable installation.
   2. Clean manholes and determine location of pulling eyes prior to cable installation.
   3. Avoid crossover of cables while pulling cables.
   4. Do not pull tight or kink cables in conduit fittings or boxes.
   5. Pull cables to be installed in a single conduit simultaneously.
   6. Fit conduit ends with plastic bell ends.
P. Provide appropriate special protection for cables in areas where cables are unavoidably exposed to hazardous conditions such as vibration or sharp corners on equipment.
Q. Modifications to communications room including installation of cable in conduits shall preserve room seal after cable installation.

R. Cable Shields
1. Install cable shields electrically continuous between terminations on terminal blocks.
2. Ground the shield of each cable on the terminal block location at the power source end of the cable ONLY to avoid ground loops.
3. Connect ground wire to ground bus.

S. Separation from EMI Sources:
1. Comply with BICSI TDMM and TIA/EIA-569-C for separating unshielded communication cable from potential EMI sources, including electrical power lines and equipment.
2. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
   b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches.
3. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
   b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches.
4. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
   b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches.
5. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of 48 inches.
6. Separation between Communications Cables and Fluorescent Fixtures: A minimum of 5 inches.

3.03 TERMINATIONS
A. Terminate all conductors. No cable shall contain unterminated elements. Make terminations at indicated devices, outlets, terminals, cross connects, and patch panels.
B. Observe minimum bending radius when training cables into final position.
C. Provide slack at terminals sufficient for two re-terminations.
D. Provide cable length sufficient to allow access for removal and inspection of equipment.
E. Provide cables continuous, without splices, between terminals within a housing, enclosure, or piece of equipment.
F. Terminate cables in order according to color code.
G. Identify individual cable pairs at each cable termination with plastic tags.
H. Terminate and identify spare pairs in each cable.
I. Perform terminations under clean and dry conditions.
J. Install terminals with tools and techniques approved by the terminal manufacturer.
K. Carefully remove cable outer sheath to the point of cable entrance at terminations. At the end of the cable sheath or covering, two layers of plastic electrical tape shall be applied.
L. Do not untwist twisted pair cables more than 1/2 inch from the point of termination to maintain cable geometry.

3.04 GROUNDING:
A. Connect ground wire terminal of each device to grounding conductor.
B. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.

3.05 CABLE IDENTIFICATION
A. Tag cables at the following locations:
   1. Termination points, and intermediate x-connect patch points.
   2. Where cable enters or exits communications rooms, enclosures, manholes, handholes, and housings.
   3. On each side of barriers the cable passes through.
   4. Every 3 feet along run of cable in cable troughs.
B. Tag cables per Sound Transit equipment identifier. All conductors, cables, equipment and communications devices shall be named and labeled with Sound Transit’s Light Rail Equipment and Facilities Numbering Plan.

3.06 FIELD INSTALLATION TESTING
A. All installed cable testing shall be recorded on the submittal approved test plan results sheets, with results summary, and submitted for approval.
B. Each twisted pair cable and multi-conductor cable shall be tested for electrical continuity. The Contractor shall measure loop resistance of each pair and triad. For pair or triad with loop resistance of more than 50 Ohms, the Contractor shall take remedial action to meet the requirement of not exceeding loop resistance of 50 Ohms.
C. Each shield conductor shall be tested for continuity. Shield drain resistance shall not exceed the loop resistance of the pair or triad cable.
D. Insulation Resistance Test

1. Measure between conductor to grounded shield and shield to ground using a 1000 Vdc megohmmeter in accordance with methods provided by cable manufacturer.

2. Ensure values provided by cable manufacturer are met.

3. Perform test after cable installation, but before terminating.

4. If the terminating is not performed immediately after cable installation, perform a second insulation resistance test just before terminating.

5. Test each cable installation after terminations are complete. Do not connect equipment cable system during test.

3.07 SYSTEM SUPPORT

A. Maintenance

1. Develop a maintenance plan that defines preventative maintenance, outage repair, and administration procedures required for conductor, cabling and equipment prior to Final Acceptance.

2. List personnel, equipment, and duration required for each procedure developed. Include frequency necessary for preventative maintenance procedures.

B. System Documentation and Record Drawings.

1. Record Documents. Provide the following documents as part of the system documentation set:

   a. Conductor and cable schedule including: Cable ID, cable length, conduit/duct bank installation location and termination locations.

   b. Drawings: Conductor and cabling schematic, Riser diagram, Point to Point cable termination details, termination panel details.

C. Final Equipment Bill of Materials lists.

END OF SECTION
PART 1 - GENERAL

1.01 WORK INCLUDED

A. Provide all labor, materials, tools, and equipment required for the complete installation of all Copper Horizontal Cabling called for in the Contract Documents.

B. In order to conform to the overall project event schedule, the cabling contractor shall survey the work areas and coordinate cabling installation with other applicable trades.

1.02 SUMMARY

A. This section includes the minimum requirements for copper horizontal balanced twisted pair cables.

B. Horizontal copper cable shall consist of Category 6 or better copper cable for all CCTV camera, VMS, telephones, door controllers, PLCs, Remote I/O and network equipment.

C. Communication circuits installed in environments where electromagnetic compatibility (EMC) can be accomplished through BICSI TDMM and TIA/EIA-569-C compliant separation from sources of electromagnetic interference (EMI) shall utilize Category 6 or better UTP (unshielded) cable.

D. Communication circuits installed in environments where electromagnetic compatibility (EMC) cannot be accomplished through BICSI TDMM and TIA/EIA-569-C compliant separation from sources of electromagnetic interference (EMI) shall utilize Category 6 or better F/UTP (shielded) cable.

1.03 REFERENCES

A. American Society of Mechanical Engineers (ASME)

   1. ASME Nuclear Quality Assurance (NQA-1)

B. Building Industry Consulting Service International (BISCI)

   1. BICSI Information Technology Systems Installation Methods Manual (ITSIMM), 7th Edition

   2. BICSI Telecommunications Distribution Methods Manual (TDMM), 13th Edition

C. Code of Federal Regulations (CFR)

   1. 10 CFR 50, Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants

D. Insulated Cable Engineers Association (ICEA)

   1. ICEA S-102-732-2009 Standard for Category 6 and 6A, 100 Ohm, Individually Unshielded Twisted Pairs, Indoor Cables (With or Without an Overall Shield) for Use in LAN Communication Wiring Systems
E. Institute of Electrical and Electronics Engineers (IEEE)
   1. IEEE 1202 Standard for Flame-Propagation Testing of Wire and Cable
F. International Organization for Standards (ISO)
   1. ISO 9001 Quality Management Systems
G. National Fire Protection Association (NFPA)
   2. NFPA 72 National Fire Alarm and Signaling Code
   3. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems
   4. NFPA 262 Standard Method of Test for Flame Travel and Smoke of Wires and Cables for Use in Air-Handling Space
H. Telecommunications Industry Association Electronic Industries Alliance (TIA/EIA)
   1. TIA/EIA-568-C Generic Telecommunications Cabling for Customer Premises
   2. TIA/EIA-568-C.1 Commercial Building Telecommunications Cabling Standard
   3. TIA/EIA-568-C.2 Balanced Twisted-Pair Telecommunication Cabling and Components Standard
   4. TIA/EIA-569-C Commercial Building Standard for Telecommunications Pathways and Spaces
   5. TIA/EIA-606A Guide: Administration Standard for the Telecommunications Infrastructure of Commercial Buildings
I. Underwriters Laboratories (UL)
   1. UL 444 Standard for Safety Communications Cables
   2. UL 969 Standard for Marking and Labeling Systems
   3. UL 1685 Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables
   4. UL 2196 Standard for Fire Test for Circuit Integrity of Fire-Resistive Power, Instrumentation, Control, and Data Cables

1.04 SUBMITTALS

A. Drawings
   1. The initial drawing list shall contain all anticipated copper Communications Cabling System drawings that will be created as part of this Contract. Standard manufacturer drawings that are generally provided with the product or subsystem need not be included in the drawing list.
   2. All drawings shall identify cable types, gauge number, and shielding-ground connections
   3. All conductors, cables, equipment and communications devices shall be named and labeled with Sound Transit’s Light Rail Equipment and Facilities Numbering Plan.
4. Each subsequent submittal after the preliminary design shall refine and update the drawing list.

5. The final as-built drawing list shall contain all Communications Cabling Systems created specifically for this Contract.

B. Test Plans
1. Pre-testing of materials test plan, and results document.
2. Cable Installation plan, and installation inspection results document.

C. Product Specification Sheets

D. Design Reviews
1. Preliminary design review
2. Final design review

E. Bill of Materials

F. Preliminary Design Document:

1. Show with block diagrams the function and geographic layout of the facility or station copper horizontal cabling and communications connections to all devices and outlets, to include:

   a. Assessment of suitability for design of duct bank, inner ducts, conduits, and general site conditions for the installation of cables and equipment.

   b. Duct bank and inner duct/conduit occupancy drawings.

   c. Duct/conduit plan drawings with distance indications on the riser diagrams.

   d. Duct and conduits with communications cable runs shall comply with all applicable NFPA 130 requirements for pathway survivability and redundancy.

   e. All cables shall be listed in a table in the Cables design document(s), noting cable distance.

   f. Hierarchical structure of all connections in communications rooms, intermediate closets and cabinets to end points, both functionally, and geographically with distances and locations noted.

   g. All Ethernet communications devices in the Cables design document(s) shall be noted for its connector and associated cable with notation of brand & model RJ45 connector to be used.

   h. All communications cable patch panels shall be shown in drawings.

   i. Spare communications wiring capacity planned to be left over, after handwork of the facility/station.

   j. All termination connectors shall be noted for type, gender, brand and model, on the drawings and tables.
k. All connections shall be noted in the Cables design document(s) for signal type running over the wire such as Ethernet, RS-232, RS-422, RS-485, ModBus, etc., on the drawings and tables.

l. All copper communications horizontal cabling shall have the terminations noted for grounding or not, both in the drawings and tables.

m. A grounding hierarchical structure shall be shown in a dedicated drawing, from remote devices back to Communications Rooms and back to main facility or station ground. Special attention shall be paid to proper ground isolation.

G. Design Documents.

1. Technical Data Sheets - Submit complete technical data sheets for the cable and ancillary equipment proposed. Demonstrate compliance with mechanical and electrical properties specified herein.

2. Manufacturer Experience - Submit information for each proposed manufacturer including experience in manufacturing communications cable, and termination equipment for rapid transit and railroad applications and quality assurance program and warranty.

3. Contractor Experience - Submit information for communications cable contractor staff including experience in installation and termination of balanced twisted pair communications cable for rapid transit and railroad applications and quality assurance program and warranty.

4. Communications Cable Lists, Plans and Drawings - Submit communications cable system schematic, plan, and detail drawings, indicating complete communications cable system, cable lengths and total end to end lengths between network switches to endpoint devices that includes patch panel lengths with device and equipment names at each end. Note equipment placement within station and cross-passages. Include profiles showing location of cabinets/racks, rack elevation drawings, including all cable termination details. Specify cable labeling in accordance with Sound Transit existing standards.

5. Material/Equipment/Assembly/Installation Details - Submittal shall include materials, equipment, assembly and installation required to carry out functions and purposes indicated in these Specifications, and to make the system suitable for the purpose for which it is intended, whether or not such materials, equipment, assembly and installation are specially indicated in the requirements of these Specifications.

6. Cable Interface Diagrams - Design submittal shall define backbone cable interfaces to copper horizontal cabling communications equipment.

7. Termination Instructions - Submit approved termination connectors.

H. Communications Cable Installation/Pull Plan.

1. Submit Installation plan as outlined herein.

I. Testing Documents.

1. Submit Test Results for each Test.

2. Factory Production Test:
   a. Submit Certified Test Report prior to shipment of cables.
3. Pre-Installation Reel Test: Submit Communications Cable Reel Test Report after shipment, but prior to installation.

J. Spare parts

1. Provide spare cable remaining on reels.
2. Provide spare termination connectors.

1.05 QUALITY ASSURANCE/QUALITY CONTROL (CABLE MANUFACTURER)

A. Cable shall be manufactured and tested under the control of a Quality Assurance program that meets the requirements of 10 CFR 50, Appendix B, as elaborated in ASME NQA-1, for materials traceability only.

B. Cable Manufacturer: Manufacturer shall have a performance record demonstrating a minimum of 30 years successful operating experience in transit, utility or industrial power applications for the insulation compound and conductor assemblies provided.

1. Quality Assurance Program: Cable manufacturers, in accordance with requirements of these Specifications, are required to have in place or implement, an effective quality assurance program adhering to the requirements of ISO 9001 to ensure purchase control performance.

2. Sample Specimens: If requested, furnish Resident Engineer sample specimens in 4 foot lengths identical to proposed cable including connectors and peripherals. Sample specimens shall remain property of Sound Transit.

1.06 QUALITY ASSURANCE (QUALIFIED COMMUNICATIONS CABLE DESIGN, INSTALLATION AND TERMINATION PERSONNEL)

A. Installer Qualifications: Cabling Installer must have personnel certified by BICSI on staff.

B. Layout Responsibility: Preparation of Design Documents, Installation Plans, Pulling Schedule, Shop Drawings and Cabling Administration Drawings development by an RCDD.

C. Installation Supervision: Installation shall be under the direct supervision of Registered Technician, who shall be present at all times when Work of this Section is performed at Project site.

D. Terminations: Trained technicians who have successfully attended an appropriate training program and have obtained a certificate as proof thereof shall perform the terminations. Sound Transit may request a copy of the certificates. These certificates may have been issued by any of the following organizations or an equivalent organization:

1. Manufacturer of the connectors or cable.

2. Training organizations (e.g., BICSI, A Telecommunications Association headquarters in Tampa, Florida; ACP [Association of Cabling Professionals™] Cabling Business Institute located in Dallas, Texas)

1.07 DELIVERY, STORAGE, AND HANDLING

A. Packing

1. Ship cable on non-returnable wooden or plastic reels.
2. Drum Diameter: Minimum 20 times the diameter of cable.
3. Reels: Substantial enough to withstand reasonable handling, designed with inner end of accessible but protected from injury.

4. Cable Ends: Sealed to prevent entrance of moisture and securely fastened to prevent ends from becoming loose during transit.

B. Marking
   1. Mark each reel on outside flange with the following information:
      a. Manufacturer's name.
      b. Contract name and number.
      c. Cable identification number.
      d. Cable length.
      e. Date of manufacture.

C. Delivery
   1. Inspect cables at time of delivery at construction site to assure no damage was done during shipping.
   2. Inspect every reel for physical damage.
   3. Submit to Resident Engineer cable reel inspection report.
   4. Replace any damaged or rejected cable promptly.

D. Storage
   1. Store cables on solid surfaces designed to support cable reels which drain adequately and do not allow accumulation of liquids, oils, or chemicals.
   2. Cables shall be protected from wetting by rain or snow, or any other sources of unintended water.
   3. Align and protect cable reels so as not to allow reel flanges to damage other reels.
   4. Provide adequate aisles and barricades to allow accessibility and to prevent construction equipment from damaging cable reels.
   5. Reseal cable ends promptly when a length is cut from reel.

E. Handling
   1. Handle cable reels using a sling and spreader attached to a shaft through the reel hubs, or by cradling both flanges between lift truck forks.
   2. Do not lift reels by top reel flange or drop from any height.
   3. Ensure lift truck forks do not touch cable surfaces on reel.
   4. Roll reels in the direction opposite the cable wind on reel.
   5. Do not lay reels flat.
PART 2 - PRODUCTS

2.01 CATEGORY 6 COPPER HORIZONTAL BALANCED TWISTED PAIR CABLELING

A. For use with cameras, VMS, telephones, door controllers, PLCs, Remote I/O and network equipment.

B. Description: 100-ohm, four pair balanced un-shielded twisted pairs 23 AWG solid soft or annealed copper polyolefin insulated conductors covered with a UV resistant jacket, in color readily available from manufacturer, typically gray, blue or white.

C. Listed and labeled by an NRTL acceptable to authorities having jurisdiction as complying with UL 444 and NFPA 70 (Article 800) for Communications, Multipurpose Plenum Rated: Type CMP complying with NFPA 262 (smoke and flame propagation testing) or permitted substitute as defined by the NEC complying with UL 1685 (low smoke) and FT4/IEEE 1202 (flame propagation) testing.

D. Cable outer jacketing to be rated for wet locations and operating temperature -20 deg. C to +90 deg. C.

E. Cables shall be marked as NRTL verified with a minimum of Category 6 rating.

F. Voltage Rating: 300V

G. Fire Resistivity: When required by AHJ per NFPA 130 cable to be 2-hour fire rated complying with UL 2196.

H. The maximum cable length for Category 6 horizontal cable is 295 feet (90m). The maximum distance from the network switch in the communications room to the device or outlet (including patch cords) is 327.8 feet (100m).

I. UTP CABLE (TYPE 1)
   3. The cable shall not incorporate an overall shield.
   4. Cable shall meet or exceed the TIA/EIA-568-C.2 permanent link performance characteristics for Category 6.

J. F/UTP CABLE (TYPE 2)
   1. Comply with TIA/EIA-568-C.2 for performance specifications of Category 6 screened (shielded) cables.
   3. The cable shall incorporate an overall helical or longitudinal plastic and metal laminated tape foil shield with 26 AWG minimum drain wire in contact with metal side of tape.
   4. Cable shall meet or exceed the TIA/EIA-568-C.2 permanent link performance characteristics for Category 6 (screened).

2.02 TRAY CABLES

1. Cables installed in trays shall be TC rated for such application. The cables shall be installed in accordance with the requirements of NFPA 70 (Article 396).
2. All cables traversing more than 50 feet in a room not installed in an enclosed raceway shall be of low smoke zero halogen (LSZH) construction.

2.03 CATEGORY 6 HORIZONTAL CABLE HARDWARE

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. ADC
3. Belden Inc
4. Dynacom Inc
5. Hubbell Premise Wiring
6. Leviton Commercial Networks Division
7. Molex Premise Networks; a division of Molex, Inc
8. Panduit Corp
9. Siemon Co. (The)
10. Tyco Electronics Corporation; AMP Products
11. Or Approved Equal

B. General Requirements for Cable Connecting Hardware: Comply with TIA/EIA-568-C.2, IDC type, with modules designed for punch-down caps or tools. Cables shall be terminated with connecting hardware of same category or higher.

C. Connecting Blocks: 110-style IDC for Category 6. Provide blocks for the number of cables terminated on the block, plus 50 percent spare. Integral with connector bodies, including plugs and jacks where indicated.

D. Cross-Connect: Modular array of connecting blocks arranged to terminate backbone cables and permit interconnection between cables.

   1. Number of Terminals per Field: One for each conductor in assigned cables.

E. Patch Panel: Rack or surface mount modular panels housing multiple-numbered jack units with IDC-type connectors at each jack for permanent termination of pair groups of installed cables.

   1. Number of Jacks per Field: One for each four-pair conductor group of indicated cables, plus spares and blank positions adequate to suit specified expansion criteria.

F. Jacks and Jack Assemblies: Modular, color-coded, eight-position modular receptacle units with integral IDC-type terminals.

G. Patch Cords: Factory-made, four-pair cables in 900 mm lengths; terminated with eight-position modular plug at each end.

   1. Employ unshielded patch cords for both UTP and F/UTP connections.
2. Patch cords shall have bend-relief-compliant boots and color-coded icons to ensure Category 6 performance. Patch cords shall have latch guards to protect against snagging.
3. Patch cords shall have color-coded boots for circuit identification.

2.04 TELECOMMUNICATIONS OUTLET/CONNECTORS

A. Jacks: 100-ohm, balanced, twisted-pair connector; four-pair, eight-position modular. Comply with TIA/EIA-568-C.1.

B. Workstation Outlets: Two-port-connector assemblies mounted in multigang faceplate.
   2. Metal Faceplate: Brass
   3. For use with snap-in jacks accommodating UTP work area cords.
      a. Flush mounting jacks, positioning the cord at a 45-degree angle.
   4. Legend: Factory labeled by silk-screening or engraving for brass.
   5. Legend: Machine printed, in the field, using adhesive-tape label.

2.05 CABLE TRAY

A. Provide cable tray in accordance with Section 26 05 33, Raceway and Boxes for Electrical Systems.

B. Communications room cable tray size: 24 inches width; 6 inches depth

C. Communications room cable tray to be of the ladder type with 6 inches rung spacing.

2.06 IDENTIFICATION TAGS

A. Material: Plastic, heat-shrinkable radiation cross-linked, thermally stabilized, flame-retarded modified polyolefin sleeves.

B. Label: List device or terminal block destination and origin, and cable number.

C. Comply with TIA/EIA-606-A and UL 969 for labeling materials, including label stocks, laminating adhesives, and inks used by label printers.

D. Sleeves: Smear resistant prior to shrinking, achieve mark permanency when shrunk without the need for permatizing equipment, or when standard ballpoint pens or high-carbon content fabric ribbons are used.

E. Chemical Resistance: Resistant to common industrial fluids including but not limited to; Freon TF, isopropyl alcohol, and Ethylene Glycol.

PART 3 - EXECUTION

3.01 INSTALLATION PLAN

A. Develop a written cable installation procedure and check-off list for approval prior to cable installation in accordance with TIA/EIA 568-C and TIA/EIA-569-C.
B. Submit information for each segment of cable to be installed.

C. Provide pulling layout including distances and tension calculations, for each cable pull.

D. Provide pulling equipment and tension monitoring devices.

E. Provide chronological plan for installing cable, including estimated time for each pull and plan for protecting cable on-reel and in slack loops during installation.

F. Installation plan shall be based on Contractor’s review of the conduit plans, and field site survey.

G. Include a cable plan and installation information for each cable pull.

H. Verify conduit size, conduit fill, conduit bend radii, manhole spacing, manhole size, raceways, ducts and associated hardware are proper prior to the intended installation.

I. Verify required cable length for each cable run prior to installation. Civil stationing appearing on referenced drawings may be used for defining locations and estimating cable lengths. Do not use existing drawings to determine final lengths and cuts. Determine actual lengths by making on-site inspections and measurements.

J. Include manufacture approved procedures for feeding cable into conduit, to maintain proper bend radii and minimize friction.

3.02 INSTALLATION

A. Install all copper horizontal cabling in accordance with BICSI ITSIMM standards and as shown on installation drawings.

B. Material and workmanship shall be of the highest quality assuring durability for minimum life expectancy of 40 years.

C. Replace all cables damaged during installation.

D. Wires and cables shall be continuous without splices between junction boxes, terminals, pull boxes, manholes and hand holes.

E. Bend Radius: Minimum 10 times the diameter of the cable or manufacturers’ recommended minimum bending radius, but not less than the radii specified in the BICSI ITSIMM “Cabling Terminations Practices” chapter.

F. Notify Resident Engineer 48 hours prior to installing cables.

G. Install cable in accordance with submitted, and Sound Transit approved, installation plan, and with service loop excess at ends of cable for maintenance and free movement of attached communications equipment.

H. Provide installation hardware to route, support, terminate, and protect cable installation.

I. Provide conduit to connect Sound Transit furnished raceways to equipment, enclosures, and devices.

J. Use lubrication when pulling cables into conduit, pipe, or duct bank.

K. Pulling cable: Comply with BICSI ITSIMM Chapter 4 “Pulling Cable”. Monitor cable pulling tensions.

L. Sealing
1. Seal cable entrance openings in equipment enclosures, rooms, and junction boxes with either a compression type fitting or pliable sealing compound after the cable is in place.

2. Use sealing compound seal area around cable where cable emerges from conduit, pipe or duct bank.

3. Sealing in accordance with NFPA 130 where required.

M. Installation in Conduit or Pipe

1. Inspect, mandrel, swab, and clean conduits and ensure a clean, smooth, concentric interior surface prior to cable installation.

2. Clean manholes and determine location of pulling eyes prior to cable installation.

3. Avoid crossover of cables while pulling cables.

4. Do not pull tight or kink cables in conduit fittings or boxes.

5. Pull cables to be installed in a single conduit simultaneously.

6. Fit conduit ends with plastic bell ends.

N. Provide appropriate special protection for cables in areas where cables are unavoidably exposed to hazardous conditions such as vibration or sharp corners on equipment.

O. Modifications to communications room including installation of cable in conduits shall preserve room seal after cable installation.

P. Cable Shields

1. Install cable shields electrically continuous between terminations on terminal blocks.

2. Ground the shield of each cable on the terminal block location at the power source end of the cable ONLY to avoid ground loops.

3. Connect ground wire to ground bus.

Q. Separation from EMI Sources:

1. Comply with BICSI TDMM and TIA/EIA-569-C for separating unshielded copper communication cable from potential EMI sources, including electrical power lines and equipment.

2. Separation between open communications cables or cables in nonmetallic raceways and unshielded power conductors and electrical equipment shall be as follows:
   b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of 12 inches.

3. Separation between communications cables in grounded metallic raceways and unshielded power lines or electrical equipment shall be as follows:
b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of 6 inches.

4. Separation between communications cables in grounded metallic raceways and power lines and electrical equipment located in grounded metallic conduits or enclosures shall be as follows:
   b. Electrical Equipment Rating between 2 and 5 kVA: A minimum of 3 inches.

5. Separation between Communications Cables and Electrical Motors and Transformers, 5 kVA or HP and Larger: A minimum of 48 inches.

6. Separation between Communications Cables and Fluorescent Fixtures: A minimum of 5 inches.

3.03 TERMINATIONS
A. Terminate all conductors. No cable shall contain unterminated elements. Make terminations at indicated devices, outlets, terminals, cross connects, and patch panels.
B. Observe minimum bending radius when training cables into final position.
C. Provide slack at terminals sufficient for two re-terminations.
D. Provide cable length sufficient to allow access for removal and inspection of equipment.
E. Provide cables continuous, without splices, between terminals within a housing, enclosure, or piece of equipment.
F. Terminate cables in order according to color code.
G. Data Cable Termination: In accordance with TIA/EIA-568-C and BICSI ITSIMM standards.
H. Identify individual cable pairs at each cable termination with plastic tags.
I. Terminate and identify spare pairs in each cable.
J. Perform terminations under clean and dry conditions.
K. Install terminals with tools and techniques approved by the terminal manufacturer.
L. Carefully remove cable outer sheath to the point of cable entrance at terminations. At the end of the cable sheath or covering, two layers of plastic electrical tape shall be applied.
M. Do not untwist UTP cables more than 1/2 inch from the point of termination to maintain cable geometry.

3.04 GROUNDING:
A. Connect ground wire terminal of each device to grounding conductor.
B. Install grounding according to BICSI TDMM, "Grounding, Bonding, and Electrical Protection" Chapter.
3.05 CABLE IDENTIFICATION

A. Tag cables at the following locations:

1. Termination points, and intermediate x-connect patch points.
2. Where cable enters or exits communications rooms, enclosures, manholes, handholes, and housings.
3. On each side of barriers the cable passes through.
4. Every 3 feet along run of cable in cable troughs.

B. Tag cables per Sound Transit equipment identifier. All conductors, cables, equipment and communications devices shall be named and labeled with Sound Transit’s Light Rail Equipment and Facilities Numbering Plan.

3.06 SYSTEM SUPPORT

A. Maintenance

1. Develop a maintenance plan that defines preventative maintenance, outage repair, and administration procedures required for communications horizontal cabling and equipment prior to Final Acceptance.
2. List personnel, equipment, and duration required for each procedure developed. Include frequency necessary for preventative maintenance procedures.

B. System Documentation and Record Drawings.

1. Record Documents. Provide the following documents as part of the system documentation set:
   a. Horizontal cable schedule including: Cable ID, cable length, conduit/duct bank installation location, termination locations, and patch cord routing.
   b. Drawings: Horizontal cabling schematic, Riser diagram, Point to Point cable termination details, termination panel details.

C. Final Equipment Bill of Materials lists.

END OF SECTION
PART 1 - GENERAL

1.01 WORK INCLUDED

A. Provide all labor, materials, and tools, field-test instruments and equipment required for the complete testing, documenting and administration of the work called for in the Contract Documents.

B. In order to conform to the overall project event schedule, the cabling contractor shall survey the work areas and coordinate cabling testing with other applicable trades.

C. In addition to the tests detailed in this document, the contractor shall notify Sound Transit or Sound Transit's representative of any additional tests that are deemed necessary to guarantee a fully functional system. The contractor shall carry out and record any additional measurement results at no additional charge.

1.02 SUMMARY

A. This Section includes the minimum requirements for the test certification, identification and administration of copper horizontal balanced twisted pair cabling.

B. This Section includes minimum requirements for:

1. Copper cabling test instruments
2. Copper cabling testing
3. Test results documentation administration

C. Testing shall be carried out in accordance with this document.

D. Testing shall be performed on each cabling link. (100% testing)

E. All tests shall be documented.

1.03 REFERENCES

A. Building Industry Consulting Service International (BISCI)
   1. BICSI Telecommunications Distribution Methods Manual (TDMM), 13th Edition

B. International Organization for Standards (ISO)
   1. ISO 2859-1 Sampling Procedures for Inspection

C. Telecommunications Industry Association Electronic Industries Alliance (TIA/EIA)
   1. TIA/EIA-1152, Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling
   3. TIA/EIA-568-1.D, Commercial Building Telecommunications Cabling Standard
4. TIA/EIA-568-C.2, Balanced Twisted-Pair Telecommunications Cabling and Components Standards

1.04 SUBMITTALS

A. Submit documents in accordance with 01 95 00 System Testing and Integration.

B. Manufacturers catalog sheets and specifications for the test equipment, including calibration records.

C. A schedule (list) of all balanced twisted-pair copper links to be tested. Including:
   1. Complete cable description
   2. Lot, batch, reel ID
   3. Physical and electrical properties (cross referenced by cable ID)

D. Sample test reports (prior to testing).

E. Final test result reports (hardcopy and electronic format) to be delivered to Resident Engineer within two days of testing.

1.05 QUALITY ASSURANCE

A. All testing procedures and field-test instruments shall comply with applicable requirements of:
   1. TIA/EIA-1152, Requirements for Field Test Instruments and Measurements for Balanced Twisted-Pair Cabling
   3. TIA/EIA-568-1.D, Commercial Building Telecommunications Cabling Standard
   4. TIA/EIA-568-C.2, Balanced Twisted-Pair Telecommunications Cabling and Components Standards

B. Trained technicians who have successfully attended an appropriate training program and have obtained a certificate as proof thereof shall execute the tests. SOUND TRANSIT MAY REQUEST A COPY OF THE CERTIFICATES. These certificates may have been issued by any of the following organizations or an equivalent organization:
   1. Manufacturer of the connectors or cable.
   2. Manufacturer of the test equipment used for the field certification.
   3. Training organizations (e.g., BICSI, A Telecommunications Association headquarters in Tampa, Florida; ACP [Association of Cabling Professionals™] Cabling Business Institute located in Dallas, Texas)

C. Sound Transit or Sound Transit’s representative shall be invited to witness and/or review field-testing. Sound Transit or Sound Transit’s representative shall be notified of the start date of the testing phase five business days before testing commences.

1.06 ACCEPTANCE OF TEST RESULTS

A. Unless otherwise specified by Sound Transit or Sound Transits representative, each cabling link shall be in tested for:
1. Wire Map
2. Length
3. Propagation Delay
4. Delay Skew
5. DC Loop Resistance
6. DC Resistance Unbalance within a pair
7. DC Resistance Unbalance between pairs
8. Insertion Loss
9. NEXT (Near-End Crosstalk)
10. PS NEXT (Power Sum Near-End Crosstalk)
11. ACR-N (Attenuation to Crosstalk Ratio Near-End)
12. PS ACR-N (Power Sum Attenuation to Crosstalk Ratio Near-End)
13. ACR-F (Attenuation to Crosstalk Ratio Far-End)
14. PS ACR-F (Power Sum Attenuation to Crosstalk Ratio Far-End)
15. Return Loss
16. TCL (Transverse Conversion Loss)
17. ELTCTL (Equal Level Transverse Conversion Transfer Loss)

The following extended test parameters pertain only to Category 6A cables and above:

18. PS ANEXT (Power Sum Alien Near-End Crosstalk) – sampled per section 3.02
19. Average PS ANEXT (Average Power Sum Alien Near-End Crosstalk) – sampled per section 3.02
20. PS AACR-F (Power Sum Alien Attenuation to Crosstalk Ratio Far-End) – sampled per section 3.02
21. Average PS AACR-F (Average Power Sum Alien Attenuation to Crosstalk Ratio Far-End) – sampled per section 3.02

B. All installed cabling Permanent Links shall be field-tested and pass the test requirements and analysis as described in Part 3. Any Permanent Link that fails these requirements shall be diagnosed and corrected. Any corrective action that must take place shall be documented and followed with a new test to prove that the corrected Permanent Link meets performance requirements. The final and passing result of the tests for all Permanent Links shall be provided in the test results documentation in accordance with Part 3.

C. Acceptance of the test results shall be given in writing after the project is fully completed and tested in accordance with Contract Documents and to the satisfaction of Sound Transit.
PART 2 - PRODUCTS

2.01 BALANCED TWISTED-PAIR CABLE TESTERS

A. The field-test instrument shall be within a 12 month calibration period.

B. Certification tester

1. Accuracy
   a. Level III (Category 6 and below) or IIle (Category 6A and above) accuracy in accordance with ANSI/TIA-1152-A
   b. Independent verification of accuracy shall be provided

2. Permanent Link Adapters
   a. RJ45 plug must meet the requirements for NEXT, FEXT and Return Loss in accordance with ANSI/TIA-568-C.2 Annex C
   b. Twisted pair Category 5e, 6, 6A, 7 or 7A cords are not permitted as their performance degrades with use and can cause false Return Loss failures

3. Results Storage
   a. Must be capable of storing > 10,000 results for all measurements found in below

4. Measurement capabilities
   a. Wire Map
   b. Length
   c. Propagation Delay
   d. Delay Skew
   e. DC Loop Resistance
   f. DC Resistance Unbalance within a pair
   g. DC Resistance Unbalance between pairs
   h. Insertion Loss
   i. NEXT (Near-End Crosstalk)
   j. PS NEXT (Power Sum Near-End Crosstalk)
   k. ACR-N (Attenuation to Crosstalk Ratio Near-End)
   l. PS ACR-N (Power Sum Attenuation to Crosstalk Ratio Near-End)
   m. ACR-F (Attenuation to Crosstalk Ratio Far-End)
   n. PS ACR-F (Power Sum Attenuation to Crosstalk Ratio Far-End)
   o. Return Loss
   p. TCL (Transverse Conversion Loss)
   q. ELTCTL (Equal Level Transverse Conversion Transfer Loss)
   r. Time Domain Reflectometer
   s. Time Domain Xtalk Analyzer
   t. PS ANEXT (Power Sum Alien Near-End Crosstalk)
   u. Average PS ANEXT (Average Power Sum Alien Near-End Crosstalk)
v. PS ACR-F (Power Sum Alien Attenuation to Crosstalk Ratio Far-End)
w. Average PS ACR-F (Average Power Sum Alien Attenuation to Crosstalk Ratio Far-End)

5. PC Software
a. Compatible with tester
b. Capable of saving test results as open format text files

2.02 DOCUMENTATION ADMINISTRATION
A. Administration of the documentation shall include test results of each Permanent Link.
B. The test result information for each link shall be recorded in the memory of the field-test instrument upon completion of the test.
C. Documentation for each measurement shall be printed in summary report formatted per BICSI TDMM Table 10.1 and transferred from the tester and saved as open format text files to portable electronic media.

PART 3 - EXECUTION

3.01 GENERAL
A. All outlets, cables, patch panels and associated components shall be fully assembled and labeled prior to field-testing. Any testing performed on incomplete systems shall be redone on completion of the work. Test cables after termination but before cross connection.

3.02 BALANCED TWISTED PAIR CABLE TESTING
A. Field-test instruments shall have the latest firmware installed.
B. Permanent Link test results, including the individual frequency measurements from the tester, shall be recorded in the test instrument upon completion of each test for subsequent uploading to PC software in which the administrative documentation (reports) may be generated.
C. Permanent Link testing shall be performed on each cabling segment (connector to connector). Sampling is not acceptable.

Items D and E pertain only to Category 6A cables and above:
D. Alien Crosstalk testing shall be performed using a sampling plan. An acceptance quality level (AQL) of 0.4%, normal inspection, general inspection level I as defined in ISO 2859-1 for populations of up to 500,000 links shall be used.

The following table represents this sampling level.

<table>
<thead>
<tr>
<th>Total number of links (N)</th>
<th>Sample size (No. of links to test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 – 33</td>
<td>3 or 0.1 x N (whichever is greatest)</td>
</tr>
<tr>
<td>34 – 3,200</td>
<td>33</td>
</tr>
<tr>
<td>3,201 – 35,000</td>
<td>126</td>
</tr>
<tr>
<td>35,001 – 150,000</td>
<td>201</td>
</tr>
<tr>
<td>150,001 – 500,000</td>
<td>315</td>
</tr>
</tbody>
</table>
E. Disturbed (Victim) links chosen for Alien Crosstalk testing shall be an equal combination of short, medium and long links.

F. Permanent Link adapters made from twisted pair Category 5e, 6, 6A, 7 or 7A cords are not permitted as their performance degrades with use and can cause false Return Loss failures.

G. The installer shall build reference links. All components shall be anchored so it is not possible to disturb them. The technician is to conduct a Permanent Link test for each type of cabling being tested each day to ensure no degradation of the tester or its Permanent Link adapters.

H. Wire Map Measurement
   1. The wire map shall verify pin-to-pin termination at each end and check for installation connectivity errors.
   2. For each of the eight conductors in the cabling, the wire map shall indicate:
      a. Continuity to the remote end
      b. Shorts between any two or more conductors
      c. Reversed pairs
      d. Split pairs
      e. Transposed pairs
      f. Distance to open on shield
      g. Any other miss-wiring
   3. The correct connectivity of telecommunications outlets/connectors is defined in TIA/EIA-568-C.2. Two color schemes are permitted. The user shall define which scheme is to be used. The field tester shall document which color scheme was used; T568A or T568B.

I. Length Measurement
   1. The length of each balanced twisted pair shall be recorded.
   2. Since physical length is determined from electrical length, the physical length of the link calculated using the pair with the shortest electrical delay shall be reported and used for making the pass or fail determination.
   3. Under Sound Transit standards for a Permanent Link, the length measurement can be no more than 295 ft. (90m) before a fail is reported.

J. Propagation Delay measurement
   1. Is the time it takes for a signal to reach the end of the link.
   2. The measurement shall be made at 10 MHz per ANSI/TIA-1152.
   3. The propagation delay of each balanced twisted pair shall be recorded.
   4. Is not to exceed 498 ns per ANSI/TIA-568-C.2 Section 6.3.18.

K. Delay Skew measurement
1. Is the difference in propagation delay @ 10 MHz between the shortest delay and the delays of the other wire pairs.

2. The delay skew of each balanced twisted pair shall be recorded.

3. Is not to exceed 44 ns per ANSI/TIA-568-C.2 Section 6.3.19.

L. DC Loop Resistance

1. Often reported as Resistance, is the DC loop resistance of both conductors in the pair.

2. The DC Resistance shall be reported for all four pairs.

3. Is not to exceed 21 Ω for all four pairs per ANSI/TIA-568-C.2 Section 6.3.1.

M. DC Resistance Unbalance within a pair

1. Is the difference in DC resistance of the two wires within the same pair.

2. The DC Resistance Unbalance within a pair shall be reported for all four pairs.

3. Is not to exceed 200 mΩ or 3%, whichever is the greatest per ANSI/TIA-568-C.2 Section 6.2.2.

N. DC Resistance Unbalance between pairs

1. The difference in DC parallel resistance of the conductors of a pair compared to the DC parallel resistance of another pair, given in the formula below:

\[ \text{Resistance Unbalance between pairs} = \left( \frac{|R_{p1} - R_{p2}|}{R_{p1} + R_{p2}} \right) \times 100\% \]

Where:
- \( R_{p1} \) is the DC parallel resistance of the conductors of a pair.
- \( R_{p2} \) is the DC parallel resistance of the conductors of another pair.

2. The DC Resistance Unbalance shall be reported for the following pairs
   a. 1,2-3,6
   b. 1,2-4,5
   c. 1,2-7,8
   d. 3,6-4,5
   e. 3,6-7,8
   f. 4,5-7,8

3. Is not to exceed 50 mΩ or 7%, whichever is the greatest.

O. Insertion Loss

1. Is the loss of signal strength over the cabling (in dB).

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
3. Both worst case and worst margins shall be reported in one direction for all four pairs.

4. Reported margins found to be within the accuracy of the field tester shall be marked with an asterisk (*).

5. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.7.

P. NEXT (Near-End Crosstalk)

1. Is the difference in amplitude (in dB) between a transmitted signal and the crosstalk received on other wire pairs at the same end of the cabling.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for the following pair combinations
   a. 1,2-3,6
   b. 1,2-4,5
   c. 1,2-7,8
   d. 3,6-4,5
   e. 3,6-7,8
   f. 4,5-7,8

4. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.8.

5. Reported margins found to be within the accuracy of the field tester shall be marked with an asterisk (*).

6. The Time Domain Xtalk data shall be stored for any marginal or failing NEXT results.

Q. PS NEXT (Power Sum Near-End Crosstalk)

1. Is the difference (in dB) between the test signal and the crosstalk from the other pairs received at the same end of the cabling.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
b. 31.25 – 100 MHz: 250 kHz

c. 100 – 250 MHz: 500 kHz

d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for all four pairs.

4. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.9.

5. Reported margins found to be within the accuracy of the field tester shall be marked with an asterisk (*).

6. The Time Domain Xtalk data shall be stored for any marginal or failing PS NEXT results.

R. ACR-N (Attenuation Crosstalk Ratio Near-End)

1. Is a calculation of NEXT minus Insertion Loss of the disturbed pair in dB.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for the following pairs
   a. 1,2-3,6
   b. 1,2-4,5
   c. 1,2-7,8
   d. 3,6-4,5
   e. 3,6-7,8
   f. 4,5-7,8

4. Although not specified in ANSI/TIA-568-C.2, it shall be recorded for all twelve possible combinations.

S. PS ACR-N (Power Sum Attenuation Crosstalk Ratio Near-End)

1. Is a calculation of PS NEXT minus Insertion Loss of the disturbed pair in dB.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for all four pairs.

4. Although not specified in ANSI/TIA-568-C.2, it shall be recorded for all eight possible combinations.

T. ACR-F (Attenuation Crosstalk Ratio Far-End)

1. Is a calculation of FEXT minus Insertion Loss of the disturbed pair in dB.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for the following pairs
   a. 1,2-3,6
   b. 1,2-4,5
   c. 1,2-7,8
   d. 3,6-1,2
   e. 3,6-4,5
   f. 3,6-7,8
   g. 4,5-1,2
   h. 4,5-3,6
   i. 4,5-7,8
   j. 7,8-1,2
   k. 7,8-3,6
   l. 7,8-4,5

4. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.11.

5. Reported margins found to be within the accuracy of the field tester shall be marked with an asterisk (*).

U. PS ACR-F (Power Sum Attenuation to Crosstalk Ratio Far-End)

1. Is a calculation of PS FEXT minus Insertion Loss of the disturbed pair in dB.

2. The frequency resolution shall be:
V. Return Loss

1. Is the difference (in dB) between the power of a transmitted signal and the power of the signals reflected back.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for all four pairs.

4. Shall be ignored at all frequencies where the Insertion Loss is less than 3 dB for that pair.

5. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.6.

6. Reported margins found to be within the accuracy of the field tester shall be marked with an asterisk (*).

7. The Time Domain Reflectometer data shall be stored for any marginal or failing Return Loss results.

W. TCL (Transverse Conversion Loss)

1. Is the ratio (in dB) between a differential mode signal inject at the near-end and the common-mode signal measured at the near-end on the same wire pair.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz
3. Both worst case and worst margins shall be reported in both directions for all four pairs.

4. Is not to exceed the limits found ANSI/TIA-568-C.2 Section 6.2.14.

X. ELTCTL (Equal Level Transverse Conversion Transfer Loss)

1. Is the ratio (in dB) between a differential mode signal inject at the near-end and the common-mode signal measured at the far end on the same wire pair minus the Insertion Loss of that pair.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. Both worst case and worst margins shall be reported in both directions for all four pairs.

4. Is not to exceed the limits found in ANSI/TIA-568-C.2 section 6.2.16.

Items Y through BB pertain only to Category 6A cables and above:

Y. PS ANEXT (Power Sum Alien Near-End Crosstalk)

1. Takes into account the combined alien crosstalk (statistical) on a receive pair from all external near-end disturbers operating simultaneously.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. The disturbed (victim) link shall have disturber links to the left and right of it and if present, links above and below it.

4. Disturber cables shall include all links within the same bundle as the disturbed (victim) link and adjacent links

5. Should be measured in both directions if the link is patch panel to patch panel. If the link is patch panel to telecommunications outlet, then it shall be measured from the patch panel end only.

6. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.21.

Z. Average PS ANEXT (Power Sum Alien Near-End Crosstalk)
1. Is calculated by averaging the individual PSANEXT loss values, in dB, for all four pairs in the disturbed (victim) link.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.22.

AA. PS AACR-F (Power Sum Alien Attenuation to Crosstalk Ratio Far-End)

1. AFEXT loss is the coupling of crosstalk at the far-end from external link pairs into a disturbed (victim) pair of the 4-pair link under test. PS AACR-F is the calculated power sum from all external pairs into the disturbed (victim) pair.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz

3. The disturbed (victim) link shall have disturber links to the left and right of it and if present, links above and below it.

4. Disturber cables shall include all links within the same bundle as the disturbed (victim) link and adjacent links

5. Should be measured in both directions if the link is patch panel to patch panel. If the link is patch panel to telecommunications outlet, then it shall be measured from the patch panel end only.

6. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.25.

BB. Average PS AACR-F (Power Sum Alien Attenuation to Crosstalk Ratio Far-End)

1. Is calculated by averaging the individual PS AACR-F values, in dB, for all four pairs in the disturbed (victim) link.

2. The frequency resolution shall be:
   a. 1 – 31.25 MHz: 150 kHz
   b. 31.25 – 100 MHz: 250 kHz
   c. 100 – 250 MHz: 500 kHz
   d. 250 – 500 MHz: 1000 kHz
3. The disturbed (victim) link shall have disturber links to the left and right of it and if present, links above and below it.

4. Disturber cables shall include all links within the same bundle as the disturbed (victim) link and adjacent links.

5. Should be measured in both directions if the link is patch panel to patch panel. If the link is patch panel to telecommunications outlet, then it shall be measured from the patch panel end only.

6. Is not to exceed the Permanent Link limits found in ANSI/TIA-568-C.2 Section 6.3.26.

3.03 ADMINISTRATION

A. Test results documentation

1. The Permanent Link test results (excluding alien xtalk testing) shall be uploaded to PC software at the end of each working day for inspection by Sound Transit or Sound Transit’s representative.

2. Test results uploaded to PC software shall be transferred onto portable electronic media to allow for the maintenance, inspection and archiving of the test records.

3. The database for the complete project, including fiber links, if applicable, shall be stored open format text files and delivered on portable electronic media prior to Sound Transit acceptance. This portable electronic media shall include a copy of PC software to allow the inspection and printing of the test reports in BICSI TDMM Table 10.1 format.

4. Circuit IDs reported by the test instrument should match the specified label ID.

5. For Permanent Link testing, the detailed test results documentation data is to be provided in PC software, hardcopy and open format text files for each tested balance twisted-pair and shall contain the following information:
   a. The overall Pass/Fail evaluation of the link-under-test
   b. The date and time the test results were saved in the memory of the tester
   c. The identification of the customer site as specified by the end-user
   d. The name of the test limit selected to execute the stored test results
   e. The name of the personnel performing the test
   f. The version of the test firmware and the version of the test limit database held within the test instrument
   g. The manufacturer, model and serial number of the field-test instrument
   h. The adapters used
   i. The factory calibration date
   j. Wire Map
   k. Propagation Delay values, for all four pairs
   l. Delay Skew values, for all four pairs
m. DC Resistance values, for all four pairs
n. DC Resistance Unbalance within a pair, values for all four pairs
o. DC Resistance Unbalance between pairs, values for all four pairs
p. Insertion Loss, worst case values for all four pairs
q. NEXT, worst case margin and worst case values, both directions
r. PS NEXT, worst case margin and worst case values, both directions
s. ACR-N, worst case margin and worst case values, both directions
t. PS ACR-N, worst case margin and worst case values, both directions
u. ACR-F, worst case margin and worst case values, both directions
v. PS ACR-F, worst case margin and worst case values, both directions
w. Return Loss, worst case margin and worst case values, both directions
x. TCL, worst case margin and worst case values, both directions
y. ELTCTL, worst case margin and worst case values, both directions.
z. Time Domain Crosstalk data if the link is marginal or fails
aa. Time Domain Reflectometer data if the link is marginal or fails

6. For Alien Crosstalk testing, the detailed test results documentation data is to be provided for each tested balance twisted-pair and shall contain the following information:

a. The overall Pass/Fail evaluation of the link-under-test
b. The date and time the measurements were made
c. The identification of the customer site as specified by the end-user
d. The name of the test limit selected to execute the stored test results
e. The name of the personnel performing the test
f. The version of the test software
g. PS ANEXT, worst case margin for all four pairs
h. Average PS ANEXT, worst case margin
i. PS AACR-F, worst case margin for all four pairs
j. Average PS AACR-F, worst case margin

END OF SECTION
SECTION 27 21 29
NETWORK SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes: furnish, install, and test of network systems for the Train Control Network (TCN) and Emergency Fire Network (EFN).

1.02 REFERENCES
A. Institute of Electrical and Electronic Engineers (IEEE)
   1. IEEE 802.1 Local and Metropolitan Area Networks – Specific Requirements Part 1: 802 Network Architecture, Interworking among 802 LANs, MANs and other wide area networks, 802 Link Security, Network Management, Protocol layers above MAC & LLC layers
   2. IEEE 802.3 Local and Metropolitan Area Networks – Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD), Access Method and Physical Layer Specifications
   3. IEEE 802.3bt DTE Power via MDI over 4-Pair (4PPoE)
   4. IEEE 1588 Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

B. Underwriters Laboratories (UL)
   1. UL 508 Safety requirements for Industrial Control Equipment.

C. Code of Federal Regulations (CFR)
   1. FCC Part15-B Regulation regarding unintentionally radiated emissions

D. International Electrotechnical Commission (IEC)
   1. IEC 60068 Environmental Testing

E. National Fire Alarm and Signaling Code (NFPA)
   1. NFPA 72 National Fire Alarm and Signaling Code.
   2. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems
   3. NFPA 1221 Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems

F. International Telecommunications Union (ITU)
   1. ITU-T Y.1564 Ethernet service activation test methodology
1.03 SUBMITTALS

A. Preliminary Design Plan:

1. Switch port requirements for each switch.

2. Preliminary optical loss budget calculations for each link span between network switches.

3. Manufacturer’s specifications and Product Data for equipment to be provided. Include switch slot modules and small form-factor pluggable (SFP) optical transceivers.

4. Equipment List, Drawings, Schematics, Bandwidth Utilization tables, Traffic Engineering, Network Security, and IP address schema. IP address schema to be developed based on overall Sound Transit Network address requirements to be provided by Sound Transit.

5. Drawings.
   b. Equipment riser diagram.
   c. Point to Point wiring detail.
   d. Power, Alarm, and Grounding schematic drawings: Show power connections, alarm, and grounding for installed network equipment.
   e. Equipment Layout Drawings: Include detailed rack and cabinet layouts for each location.

6. Network equipment tagging scheme including: patch cords, power, alarm, and grounds.

B. Final Design Plan:

1. Update of Preliminary Design Plan to include final configuration data, final drawing updates, and final switch configuration including:
   b. Final equipment and component lists, per node location.

C. Network Installation Plan:

1. Installation plan for each location. This procedure shall be prepared based on Contractor’s review of the installation location, and field site survey (Site Verification). Include equipment installation, and information for cabling and wiring connections.

D. Test Documents.

1. Testing documents in accordance with Sound Transit Commissioning Requirements.

2. Factory Acceptance Testing (FAT) procedure for approval detailing Network equipment functions, configurations, settings, and equipment selections in accordance with requirements herein.
3. Test procedures and test results for factory testing, and for each test as part of network installation.

4. Site Acceptance Testing (SAT) procedure for approval detailing Network equipment functions, configurations, settings, troubleshooting procedures and equipment selections in accordance with requirements herein.

E. Record Documentation.

1. Supply final As-Built Drawings that include System Architecture, detailed Network schematics, and detailed installation drawings for Communication Network Equipment. These drawings shall be an image of what is installed in the field by the final completion date. Redlines and updated IFC drawings are not acceptable. The drawings shall meet ST CAD standards.

2. Supply complete Network System Configuration documentation, indicating network equipment configuration settings, Internet Protocol (IP) address scheme, Virtual Local Area Network (VLAN) configuration, and quality of service assignments. Provide as formatted Excel document, in version to be approved by Resident Engineer.

3. Supply a complete testing documentation following the Service performance test report format described in ITU Y.1564

F. System Support.

1. Copies of manufacturer support and warranty agreements for equipment, software, and systems provided. Provide contact information for equipment and software manufacturers in accordance with delivered support and warranty agreements.

2. Operating and Maintenance instructions, Operation and Maintenance (O&M) Manuals for each system provided and a Renewal Parts Catalog.

G. Maintenance Personnel Training

1. Training plan for ST or KCM employees tasked with the system maintenance, including any presentation slides used in personnel training. ST intends recording the training sessions for future training.

1.04 QUALITY ASSURANCE

A. Network Contractor Qualifications.

1. Network systems work requires that the specifications request dedicated IT network engineers and technicians with specialized knowledge and training.

2. Network Contractors shall be certified by the network equipment manufacturer for the network equipment provided.

B. Network Engineer.

1. The Network Engineer shall be associated with all phases of planning, designing, network integration, cut-over supervision, testing, and deployment of the Communications networks.

2. The Network Engineer shall act as single point of contact with the Resident Engineer.
3. The Network Engineer shall have a minimum of 10 years of hands-on professional experience and proven knowledge of network technologies including Fiber Optic, Ethernet and IP Communications systems. This shall include design of network systems and providing comprehensive system engineering and integration services, on a turnkey basis.

4. Proper procedures for assessing the network personnel performance shall be defined with alternatives for replacing personnel that has been found unable or unqualified to perform their duties.

PART 2 - PRODUCTS

2.01 GENERAL

A. Train Control Network (TCN) and Emergency Fire Network (EFN).

1. Sound Transit will furnish and configure all EFN and TCN network switches for this Contract in accordance with the contract network design. The Contractor shall provide end device network requirements and coordinate with Sound Transit to ensure the Contractor's work complements that of Sound Transit to deliver a fully integrated solution as shown in the Contract Documents.

2. The network equipment information shall be provided to Sound Transit with enough time for purchase, delivery and configuration and testing before the equipment is required for any other purpose.

3. Sound Transit will provide Network switches in accordance with approved Sound Transit vendor list of switch equipment. Contractor shall determine switch equipment port quantities per tunnel and station device network requirements. This shall include providing switch requirements, installation, and testing.

2.02 TCN/EFN ETHERNET NETWORK DEVICES

A. ST wants to build a network based in open standards. Proprietary implementations shall be avoided.

B. In general, any network device shall support:

1. Technology
   a. Standards IEEE 802.3 for 10BaseT
   b. IEEE 802.3u for 100BaseT(X) and 100BaseFX
   c. IEEE 802.3ab for 1000BaseT(X)
   d. IEEE 802.3z for 1000BaseSX/LX/LHX/ZX
   e. IEEE 802.3ae for 10 Gigabit Ethernet
   f. IEEE 802.3af/bt for PoE/PoE+/4PPoE output
   g. IEEE 802.3x for Flow Control
   h. IEEE 802.1D-2004 for Spanning Tree Protocol
   i. IEEE 802.1w for Rapid Spanning Tree Protocol
   j. IEEE 802.1s for Multiple Spanning Tree Protocol
k. IEEE 802.1Q for VLAN Tagging
l. IEEE 802.1p for Class of Service
m. IEEE 802.1X for Authentication
n. IEEE 802.3ad for Port Trunk with LACP

2. Software Features
   a. IPv4 and IPv6 support, in and out of band management, SNMP v3 or later, LLDP, Port Mirror, DDM, RMON, DHCP Server/Client, DHCP Option 66/67/82, BootP, TFTP, SMTP, RARP, Telnet, Syslog, SNMP Inform, Flow Control, Back Pressure Flow Control
   b. Filter 802.1Q VLAN, Q-in-Q VLAN, GVRP, IGMP v1/v2/v3, GMRP
   c. Redundancy Protocols STP, RSTP, MSTP, Link Aggregation
   d. Security RADIUS, TACACS+, SSL, SSH, Broadcast Storm Protection, Port Lock, Access Control Lists
   e. Unicast Routing Static Routing, RIPV1/V2, OSPF, BGP
   f. Multicast Routing DVMRP, PIM-DM, PIM-SM, PIM-SSM
   g. Time Management SNTP, NTP Server/Client, IEEE 1588v2 PTP
   h. Industrial Protocols EtherNet/IP, Modbus/TCP support
   i. MIB MIB-II, Ethernet-like MIB, P-BRIDGE MIB, Q-BRIDGE MIB, Bridge MIB, RSTP MIB, RMON MIB Groups 1, 2, 3, 9
   j. Routing Redundancy VRRP

C. Core Network: The specification shall require high-traffic/High-availability network switches based on:
   1. A traffic estimation study with the required design capacities.
   2. Based on the study mentioned above, define the switch brand and mode required to meet the capacity
   3. Provide at least 50% spare fabric traffic capacity
   4. Ability for redundant power supplies and easy fan replacement
   5. Layer 3 licenses included
   6. OSPF and BGP support
   7. MPLS and VPLS support
   8. IPv6 support
   9. High capacity host zSFP+ interface
   10. 10/100Mpbs, 1Gps, 10Gbps Ethernet interfaces

D. Distribution Layer: The specification shall require at each station redundant high-capacity router/switches with the following features:
1. Redundant power supplies
2. Layer 3 licenses included
3. OSPF and BGP capable
4. IPv6 capable
5. Provide at least 50% spare fabric traffic capacity
6. High capacity host zSFP+ interface
7. 10/100Mbps, 1Gps Ethernet interfaces

E. Access layer: The specification shall require all access layer switches to meet industrial grade devices, intended for harsh environment operation with at least the following features:
   1. Redundant power supplies
   2. Layer 3 licenses included
   3. IPv6 capable
   4. Provide at least 30% spare fabric traffic capacity
   5. At least 4 host zSFP+ interfaces
   6. 10/100Mbps, 1Gps Ethernet interfaces
   7. Provide at least 50% 802.3bt (4PPoE) ports with backwards compatibility.

F. Small Form-factor Pluggable Transceiver: The specification shall require the use of SFP modules for optical network interconnecting, they shall offer the following features:
   1. Brand independent modules
   2. SFP/SFP+/zSFP+ option availability
   3. Ability to use different fiber optic types with different module models
   4. Real-time testing and diagnostics
   5. Hot swappable
   6. Single strand bidirectional link support

G. EFN Specific devices requirements: EFN devices require industrial ratings for all its components, therefore require the following features:
   1. At least Ingress Protection 66 rating
   2. Hot-swappable redundant power supplies
   3. Layer 3 licenses included
   4. OSPF and BGP capable
   5. IPv6 capable
   6. Provide at least 50% spare fabric traffic capacity
7. High capacity host zSFP+ interface
8. 10/100Mpbs, 1Gps Ethernet interfaces
9. Fanless, -10 to 60°C operating temperature range
10. At least 50% 802.3bt (4PPoE) ports with backwards compatibility.

H. Network Management: All network devices shall be remotely manageable using SNMP v3 or higher, with MIB II support. The specification shall require the devices to be managed with the current Sound Transit supported SNMP manager and provide the required licenses to support the new devices.

I. Network synchronization: All network devices shall be able to synchronize with Master Clock, using IEEE 1588v2 protocol. If the network is isolated and/or an existing clock is not available, the specification shall include a local GPS synchronized clock. NTP/SNTP is not acceptable.

J. IP Addressing scheme: Develop with Sound Transit concurrence the IP Scheme to be used. ST is interested in migration towards an IPv6 addressing scheme so the specifications shall allow an IPv4 implementation but shall require a path to IPv6.

K. VLAN Configuration: All VLANs shall be in accordance with ST defined VLAN structure. Network devices shall support 802.1Q.

L. Quality of Service (QoS): Data transmitted over the TCN/EFN shall have Quality of Service (QoS) requirements in accordance with QoS as configured by Sound Transit.

PART 3 - EXECUTION

3.01 GENERAL:

A. All work shall be completed in a professional manner to implement complete and functional systems or subsystems as specified. All installation and related activities shall be coordinated through the Resident Engineer and performed in accordance with all site access and work hour restrictions specified.

B. Install required power supplies, cabling, conduit, connectors, patch cords, and all other miscellaneous items required for a fully functional network.

C. The equipment configuration shown in the Contract Drawings is typical. Equipment cabinets, router, switches, cable managements and other ancillary equipment may be located within reasonable limits as necessary to avoid conflicts with light fixtures, structural elements, ductwork, and other equipment mounted in stations.

D. The network contractor shall coordinate conduit and cable routing and all installation details with other trades and disciplines and make all required interconnection wiring at the OMF, stations, cars and other locations specified.

E. All equipment not suitable for 19” rack mounting shall be installed in a DIN-rail with an adapting bracket.

F. Once the network is installed, the contractor shall perform bandwidth testing in accordance to ITU-T Y.1564 Ethernet service activation test methodology.

END OF SECTION
SECTION 27 51 16
PUBLIC ADDRESS VARIABLE MESSAGE SIGNS (DIGITAL DISPLAYS)

PART 1 - GENERAL

1.01 WORK INCLUDED

A. Provide all labor, materials, tools and equipment required for the complete design, installation, and testing of a fully integrated Public Address Variable Message Sign (PA/VMS) system.

B. Provide all hardware, software, manuals, licenses, and training for operation and maintenance of the PA/VMS system.

C. Integrate Close Circuit Television (CCTV) IP cameras, within packaged digital display housings.

1.02 SUMMARY

A. This section includes the minimum requirements for the following types of VMS signs per the station specific drawings:

1. Standard Variable Message Signs – Flat Panel TV (FPTV) Monitors

2. Double Sided Bar Variable Message Signs – Stretched Displays

3. Single and Double Sided Bar Variable Message Signs – Stretched Displays (Existing Retrofits)

B. Public address variable message signs shall consist of display panels, embedded hardware, weatherproof, tamper proof, vandal resistant housings and mounting hardware integrated into self-contained packaged signs for use within station public areas for displaying textual and graphical messages, including life safety emergency information.

C. The digital displays must integrate with the overall Sound Transit Passenger Information Management System (PIMS) for display of next train arrival and destination information to the riding public. Public address variable message sign integration shall be via the local station control unit (SCU).

1.03 REFERENCES

A. American Society of Mechanical Engineers (ASME)

1. ASME Nuclear Quality Assurance (NQA-1)

B. ASTM International

1. ASTM D1003-00, Standard Test Method for Haze and Luminous Transmittance of Transparent Plastics

C. Code of Federal Regulations (CFR)

1. 10 CFR 50, Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
2. 42 U.S.C. 12181 - Americans with Disabilities Act of 1990 (Title III) (ADA)

D. Federal Communications Commission (FCC)
   1. 47 CFR Part 15, Subpart B, Class A – Unintentional Radiators

E. International Building Code (IBC)
   IBC Chapter 16 – Structural Design

F. International Organization for Standards (ISO)
   1. ISO 9001 Quality Management Systems

G. United States Military Standards (MIL)
   1. MIL-STD-810G, Part 2, Test Method 516.7 Shock

H. National Fire Protection Association (NFPA)

I. Underwriters Laboratories
   1. UL 48 – Standard for Electric Signs
   2. UL 508 – Standard for Industrial Control Equipment
   3. UL 1449 – Safety Standard for Surge Protective Devices
   4. UL 60950-1 – Information Technology Equipment – Safety- Part 1

1.04 COORDINATION

Contractor shall coordinate with the following specification sections to furnish complete and functioning digital displays:

A. 27 15 02 Communications Conductors and Cables
B. 27 15 13 Communications Copper Horizontal Cabling
C. 27 21 29 Network Equipment
D. 27 51 23 Audio Paging and Messaging Integration
E. 28 23 00 Closed Circuit Television System

1.05 VMS SYSTEM DESCRIPTION

A. The VMS System shall consist of new and unused digital display equipment, software, firmware, raceways, and wiring as required to provide a complete and operating system in full compliance with the Contract.

   2. Media Content software for networked content management. Provide interface to 3rd party media content interface.
3. VMS Management Software: Users must be able to manage and configure signs using content management tools.

4. Local station VMS controller to provide interface between SCU and station paging controller as shown on Contract Drawings.

1.06 VMS SYSTEM FUNCTIONAL REQUIREMENTS

A. Central Control System:
   1. VMS Controller Media Software:
      a. Provides interface with servers via IP based data communication link at the OCC.
      b. Provide the capability to interface to 3rd party content providers for media content via internet through a Sound Transit firewall connection.
      c. Coordinate with Sound Transit’s IT department for the connection.
   2. VMS Content Management Application Software:
      a. Integrate with PIMS. The extension shall provide Sound Transit operations the capability of configuration and management of VMS displays application and locally generated content.

B. Display Message Content Sources:
   1. The VMS controller will interface with local station control units (SCUs). This unit provides VMS and public address integration and transport of signals from the OCC.
   2. All messages shall be shown in text on the appropriate display(s) and annunciated verbally over the station public address system in the appropriate zone.
   3. VMS text messaging must be viewable in accordance with Americans with Disabilities Act ADAAG requirements, CFR-42 U.S.C. 12181, and Part 36 App. A.
   4. VMS must support IP based streamed live and recorded media content.
   5. VMS shall be capable of displaying current time in AM/PM Format HH:MM XX and shall automatically adjust for daylight savings time. Time shall be synchronized to within one (1) second of a Sound Transit time. Coordinate interface to the source with Sound Transit.
   6. The VMS shall display next train, train arrival time and train destination.
   7. At terminus stations the VMS shall also display the next departing train. This determination shall be based on train tracking and first in/first out logic.
   8. VMS shall interface to the station FACP via emergency ventilation system PLCs so that locally stored messages in the SCU can be displayed.

C. System Compatibility
   1. Contractor shall coordinate with Sound Transit to ensure compatibility of all manufacturer supplied firmware, software, operating systems and
communications interface drivers with all PIMS equipment, content management systems, sources and software.

2. Contractor shall require sign manufacturer to provide representative sample equipment for use in compatibility testing if requested by Sound Transit.

1.07 SUBMITTALS

A. The Contractor shall provide submittals in accordance section 01 38 00 Submittal Procedures. As a minimum the Contractor shall provide a preliminary, final and as-built submittal for subsystems and products specified in this section.

B. Drawings:

1. A comprehensive drawing list of all Public Address Variable Message Signs drawings to be created for this Contract. As a minimum the drawing list shall be submitted with the preliminary, final and as-built submittals, and any other major digital displays submittal.

2. The initial drawing list shall contain all anticipated digital displays drawings that will be created as part of this Contract. Standard manufacturer drawings that are generally provided with the product or subsystem need not be included in the drawing list, even though they will be submitted for Sound Transit approval.

3. Numbering of the digital displays drawings shall generally follow Sound Transit’s numbering scheme and shall be submitted for Sound Transit’s approval.

4. Each subsequent submittal after the preliminary design shall refine and update the drawing list.

5. The final as-built drawing list shall contain all digital displays drawings created specifically for this Contract.

6. Naming and numbering of devices shall follow Sound Transit’s Light Rail Equipment and Facilities Numbering Plan.

C. Product Data:

1. Packaged sign manufacturer qualifications, as specified herein.

2. Cut sheets for the proposed equipment, including modular components, power, recommended cabling, and grounding, housing access, mounting, certifications and environmental considerations demonstrating compliance with requirements specified herein.

3. Housing and package shop drawings, including an illustration of the recommended installation method.

4. Riser diagrams

5. Package components exploded views with Bill of Materials

6. Display schematics, including wiring terminals, AC power distribution, DC power distribution, and control signal distribution.

7. O&M and display control software operator’s manual(s).

8. Recommended spare parts list.
1.08 QUALITY ASSURANCE/QUALITY CONTROL (MANUFACTURER)
A. Digital displays and packaged signs shall be manufactured and tested under the control of a Quality Assurance program that meets the requirements of 10 CFR 50, Appendix B, as elaborated in ASME NQA-1, for materials traceability only.
B. Packaged Sign Manufacturer: Manufacturer shall have a performance record demonstrating a minimum of 15 years successful operating experience in transit applications for the assemblies provided.
C. Quality Assurance Program: Sign manufacturers, in accordance with requirements of these Specifications, are required to have in place or implement, an effective quality assurance program adhering to the requirements of ISO 9001 to ensure purchase control performance.

1.09 QUALITY ASSURANCE (QUALIFIED INSTALLER)
Installer Qualifications: Installation of the VMS system to be performed by a qualified contractor with extensive experience in digital signage installation, testing, and integration or have received adequate training by digital display manufacturer.

1.10 AVOIDANCE OF OBSOLESCENCE
A. Contractor shall coordinate with sign manufacturer all procurement, supply, fabrication and delivery activities to ensure no obsolete or unsupportable equipment is handed over to Sound Transit at time of Substantial Completion.
B. All equipment, components, embedded hardware, firmware, operating systems and software shall be certified as current and supportable for a minimum of three (3) years following Substantial Completion.
C. Contractor shall require sign manufacturer to conduct onsite upgrades of any and all components, embedded hardware, firmware, operating systems and software that become obsolete or unsupportable after delivery and prior to Substantial Completion at no additional cost to Sound Transit.

1.11 DELIVERY, STORAGE AND HANDLING
A. General: Delivery, storage, and handling of the digital displays and packaged sign equipment shall be in accordance with the manufacturer’s recommendations.
B. Ordering: The manufacturer’s ordering instructions and lead-time requirements must be followed in order to avoid installation delays.
C. Delivery: The digital displays and packaged sign equipment shall be delivered in the manufacturer’s original, unopened, undamaged container with identification labels intact.
D. Storage and Protection: The digital displays and packaged sign equipment shall be stored and protected from exposure to harmful weather conditions and at the environmental conditions recommended by the manufacturer.

PART 2 - PRODUCTS

2.01 VARIABLE MESSAGE SIGNS
A. Description: Packaged, rugged, vandal resistant, tamper-proof, fully sealed, outdoor rated, high brightness LCD transit passenger information digital displays. Constructed from standard size full or tiled sets. Packages to incorporate CCTV cameras (quantity
and type) as noted on contract drawings. Signs shall be single or double sided as noted on contract drawings.

B. Display Panel

1. Type: Direct LED (DLED) or Organic LED (OLED) backlit Liquid Crystal Display (LCD)
2. Pixel Pitch: minimum pixel pitch of 0.22mm x 0.65mm
3. Brightness: minimum 1000 nits (cd/m2)
4. Contrast Ratio (Typ.)
   a. Static Contrast Ratio: minimum 3000:1
   b. Dynamic Contrast Ratio: minimum 50,000:1
5. Viewing Angles: 178°:178°
6. Response Time: minimum response time of 10ms
7. Refresh Rate: 60Hz minimum
8. Display Colors: 10bit Dithering, 1.06 Billion colors, conventional RGB stripe arrangement
9. OSD: English (default)

C. Connectivity

1. Signal Input: DVI (720p/1080i/1080p), VGA, HDMI, Composite Video or data port
2. Data Input: Ethernet port (RJ45), RS-232C, signs should have ability to incorporate future wireless interface(s) (Wi-Fi 802.11ac, LTE modem, etc.)
3. Remote Input: IR Remote Control
4. External Sensor: IR, Ambient Light

D. Embedded Hardware (VMS Controller)

1. Processor: Dual Core CPU
2. Cache Memory: L1: 32KB/32KB, L2: 1MB
3. Clock Speed: minimum 1.0 GHz
4. Main Memory: 8GB DDR3
5. Storage: 128GB SSD
6. Graphics: 2D & 3D Graphics engine with standard open API (OpenGL or equivalent), supports up to 1920 x 1080, 32bpp
7. Multimedia
   a. Video Decoder: MPEG-1/2, H.264/AVC (Dual), VC-1, JPEG, PNG, VP8
   b. Audio Decoder: AC3 (DD), MPEG, DTS
8. I/O Ports: USB 2.0

9. Operating System: Latest supported Windows compatible with content management and control systems

10. Diagnostics:
   a. Self-monitoring: internal temperature control, auto-adjust screen brightness, pixel detection, diagnostic logs
   b. Network (SNMP managed)

E. Electrical
1. Power Supply: 100-240 VAC, 60Hz
2. Power Connection: Accessible standard power plug, no electrician access required
3. Power Management: VESA DPMS Compliant
4. Safety: Listed and labeled by an NRTL acceptable to authorities having jurisdiction complying with NFPA 70 (NEC)

F. Mechanical
1. Housing:
   a. Digital signs to be packaged within an integrated fully sealed outdoor rated, weatherproof, vandal resistant, tamper-proof housing.
   b. Housings to incorporate CCTV cameras. Cameras provided and installed by Contractor.
   c. IP65 weatherproof rating minimum. Weatherproof rating must include incorporation of CCTV cameras.
   d. Housing shall incorporate tamper-proof hardware and access latches. Housing shall provide hinged maintenance door access to internal components. Doors shall lock in open position.
2. Material & Finish: Vandal resistant steel or aluminum housing, powder coated matte black
3. Protection Glass: Shall be laminated IK08 impact rated safety glass, (additionally tempered if necessary to meet impact rating and remain within maximum weight requirements)anti-glare/anti-reflective (blue color)coating:
   a. Luminous Reflectance $\rho_{\lambda} < 1\%$
   b. Luminous Transmittance $T_{\lambda} > 98\%$ (per ASTM D1003-00)
4. Bezel: minimize bezel to meet active display area requirements
5. Tilt: Adjustable (at a minimum shall be adjustable at time of install)
G. Environmental
1. Operating Temperature: -20°C to +40°C (-4°F to +104°F)
2. Humidity: 20% to 80%
3. Sunlight Exposure: Full Direct Sunlight
4. Shock & Vibration
   b. Perform testing using Classical Pulse option requirements or equivalent.
   c. Tests shall incorporate all applicable Seismic Zone 4 criteria.

H. Performance
1. Service Life: Package service life shall be 100,000 hours of continuous operation.
2. Component MTBF: No single component or module shall fail within 40,000 hours of continuous operation.

I. Serviceability
1. Packages and sets shall be of modular design allowing for in-line replacement of all wearable components including but not limited to: protective glass, display panel, power supply, backlight, processor, network interface card and fans.
2. Packages shall be capable of being serviced by a single individual including housing access.
3. Packaged signs and all internal components shall be furnished with a 3-year warranty covering parts and labor from the sign manufacturer.

J. Certification
1. Safety certification:
   a. Complete packaged signs shall be listed and labeled by an NRTL acceptable to the authority having jurisdiction as complying with UL 48, UL 508 or UL 60950-1 (must include Annex T compliance for water ingress).
   b. Power supplies shall incorporate surge suppression devices on incoming power that comply with UL 1449 or equivalent.
2. Electromagnetic Compatibility (EMC): Packaged signs shall comply with FCC Part 15, Subpart B, Class A.

K. STANDARD VARIABLE MESSAGE SIGNS – FLAT PANEL TV (FPTV) MONITORS
1. For use in transit stations and transit platform kiosks where clearances and headroom allow. See contract drawings for specific locations.
2. Display Panel
   a. Diagonal Size: 46” to 55”
b. Resolution: 1920 x 1080, 16:9

c. Active Display Area: minimum active display area of 40.08” x 22.54” (1018mm x 572mm)

3. Mechanical
   a. Mounting: FDMI VESA compliant. (MIS-F)
   b. Dimensions: maximum dimensions including CCTV cameras 72”W x 40”H x 12”D. Where two signs are called for mounted back to back maximum of 24”D plus mounting bracket depth.
   c. Weight: maximum weight for packaged sign including CCTV cameras and mounting hardware not to exceed 250 lbs. Where two signs are called for mounted back to back pendant hanger has maximum of 500 lbs. for combination.

4. Electrical
   a. Power Consumption: maximum power consumption 350W

L. DOUBLE SIDED BAR VARIABLE MESSAGE SIGNS – STRETCHED DISPLAYS

1. For use in transit tunnels, transit stations and platforms where clearance and headroom limitations are restrictive. See contract drawings for specific locations.

2. Display Panel
   a. Diagonal: 42” Stretched
   b. Resolution: 1920 x 480, 16:4
   c. Active Display Area: minimum active display area of 40.09” x 10.2” (1040mm x 260mm)

3. Mechanical
   a. Mounting: FDMI VESA compliant (JMIS-F) or custom ceiling mount via pipe pendant hanger.
   b. Dimensions: maximum dimensions including CCTV cameras 77”W x 22”H x 24”D
   c. Weight: maximum weight for packaged signs (double sided) including CCTV cameras and mounting hardware not to exceed 200 lbs.

4. Electrical
   a. Power Consumption: maximum power consumption 200W

M. BAR VARIABLE MESSAGE SIGNS – STRETCHED DISPLAYS (EXISTING RETROFITS)

1. For use in existing transit tunnels, existing transit stations and platforms to replace existing single and double sided LED bar displays.

2. Display Panel
   a. Diagonal: 42” Stretched
3. Mechanical
   a. Mounting: FDMI VESA compliant (JMIS-F) or custom ceiling mount via pipe pendant hanger. Contractor to modify pendant hangers and connections as necessary for new signs.
   b. Dimensions: maximum dimensions including CCTV cameras 77”W x 22”H x 24”D. Where single sided signs are called for maximum of 12”D.
   c. Weight
      1) Maximum weight for single sided packaged sign including CCTV cameras and mounting hardware not to exceed 165 lbs.
      2) Double sided packaged signs including CCTV cameras and mounting hardware to not exceed 200lbs.
      3) Contractor to confirm weight limitations of all existing pendant hangers.
      4) Pendant hangers found unable to support actual sign package weight to be upgraded by Contractor at no additional cost to Sound Transit.
      5) Coordinate with Sound Transit for resolution of overall structure found unable to bear actual sign package weight

4. Electrical
   a. Power Consumption: maximum power consumption 200W

2.02 MAINTENANCE LAPTOP

A. Provide a VMS maintenance laptop. The laptop shall be loaded with required application software to support VMS system configuration, installation, testing, and maintenance with required licensing transferred to Sound Transit and in coordination with Sound Transit.

B. Provide a Dell laptop. The model number shall be coordinated with Sound Transit.

C. Equip each laptop with the following software. The version of the software shall be coordinated with Sound Transit prior to purchase:
   1. Latest supportable Microsoft Windows operating system.
   2. Microsoft Office.
   3. Consult with Sound Transit IT for anti-malware product to be provided with this laptop
   5. Application software necessary for management, maintenance and support of VMS system: Digital Signage Management Software and Media Content Server Software.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Install as indicated in conformance with manufacturer’s directions for conditions of application.

B. Coordinate with civil contracts for VMS installation. Verify VMS enclosure mounting point location meets requirements in accordance with Contract Drawings.

C. Civil contractor will install pendant hangers for attachment to any canopy structure. Contractor shall trim and thread these members to ensure that the VMS and any integrated CCTV cameras are at 9'-0" Above Finished Floor (AFF).

D. Where signs are mounted to floor mounted structures or cantilevered support brackets, follow designs per contract drawings.

E. Installation shall comply with International Building Code Chapter 16, including sections on seismic design and wind pressure for non-structural components.

F. CCTV Cameras: Install CCTV cameras within VMS housings as shown on Contract Drawings. VMS mounted CCTV cameras are part of the station CCTV camera system, and do not integrate directly to the VMS system. The VMS housing functions as a mounting and camera wiring access point only.

G. Wiring will enter through pendant hangers extending from ceiling to the sign housing mounting; junction boxes and conduit shall be concealed from public view.

3.02 LOCAL STATION CONTROL UNITS INTERFACE

A. The SCU facilitates synchronizing the visual content from the VMS with the audible message from the public address system. It also provides the interface to the OCC and the FACP.

B. Provide an interface to SCUs as described in section 27 51 23 Audio Paging and Messaging Integration.

C. The Contractor shall provide means to pass messages from the SCU to the VMS.

3.03 DATA TRANSMISSION SYSTEM

A. VMS displays shall utilize the TCN for IP data transmission. VMS displays shall utilize CAT6 UTP for IP data cabling. Reference Section 27 15 13 Communications Copper Horizontal Cabling for cabling requirements.

B. VMS displays shall be connected via CAT6 100BASE-TX RJ45 terminated cables and patch cords to the associated TCN Ethernet switch located in the communication distribution cabinets or communication room racks.

C. IP address configuration and VLAN assignments shall be determined based on current Sound Transit IT requirements and requested from Sound Transit. Reference Section 27 21 29 Network Equipment for TCN requirements.

3.04 CYBERSECURITY

A. The Operating Systems of digital display embedded hardware and maintenance laptop shall be patched with the latest available patches at the time of installation.
B. All equipment capable of IP-based communications shall undergo a vulnerability scan using a vulnerability scanner product (e.g. Nessus, Qualys, Rapid7) and all identified vulnerabilities shall be remediated prior to installation on site.

C. All equipment capable of IP-based communications shall have any default passwords provided by the manufacturer changed prior to system acceptance. New passwords shall be provided securely to Sound Transit during system acceptance.

3.05 SOURCE QUALITY CONTROL

A. Factory Functional Testing:

1. Test each type of VMS that will be installed in the field.

2. The tests shall include each type of video source that the VMS will be required to display.

3. Perform the following tests:
   a. Test the data interface with an SCU and with the Sound Transit PIMS software.
   b. Test input terminals and data interface for alarm input contact closure and to trigger local stored emergency messages.
   c. Message Display Times
   d. Message Features: Horizontal scroll, vertical page flip, flash, variable height.
   e. Multiple screen sections zones and live IP video, with simultaneous text scrolling/page flipping.
   f. Emergency override messaging, via contact closure.
   g. Maximum viewing Angle.
   h. Brightness and/or Contrast.

4. Document test results. Demonstrate VMS meets all requirements for the tested parameter listed in this section.

3.06 FIELD QUALITY CONTROL

A. Test Equipment:

1. Provide test equipment for maintenance and management in order to support network equipment.

2. Field Tests (perform for each VMS):
   a. Receipt of each type of video source
   b. Confirm the data interface with an SCU
   c. Input terminals and data interface for alarm input contact closure and to trigger local stored emergency messages.
   d. Message Display Times.
e. Message Features: Horizontal scroll, vertical page flip, flash, variable height.

f. Multiple screen sections zones and live IP video, with simultaneous text scrolling/page flipping.

g. Emergency override messaging, via contact closure.

h. Maximum viewing Angle.

i. Brightness and/or contrast.

3. Document test results. To pass the test the VMS shall meet the requirements for the tested parameter listed in this section.

3.07 CLOSEOUT ACTIVITIES

A. Training:

1. Develop Training Plan. Submit prior to training for Sound Transit approval.

2. Contractor to prepare hard copies of training materials to be used in training.

3. Contractor to video record training sessions and provide a Blu-ray disk and MPEG-4 file for use later by Sound Transit.

B. Equipment to be turned over to Resident Engineer at Substantial Completion.

3.08 MAINTENANCE

A. Maintenance Plan: Develop a maintenance plan that details preventative maintenance, outage repair, and administration procedures required for VMS equipment prior to Final Acceptance.

1. List personnel, equipment, and duration required for each procedure developed.

2. Include frequency necessary for preventative maintenance procedures.

3.09 SPARE PARTS

A. Provide two of each type of VMS packaged sign units including complete housing and mounting equipment.

END OF SECTION
PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the establishment and maintenance of a Communications System Reliability Program, which shall be applied to obtain a valid assessment of the Mean Time Between Failures (MTBF) capabilities of the designated equipment and subsystems furnished under this Contract. This program shall include:

1. The furnishing of predicted design reliabilities.
2. Field reliability testing.
3. Continual comparisons of field reliability testing.
4. All corrective measures required to obtain satisfactory performance.

B. The subsystems to be tested for system reliability compliance shall consist of:

1. Emergency and Passenger Telephone System
2. Public Address System
3. Closed Circuit Television System
4. Radio System
5. SCADA Train Control System
6. Emergency Ventilation System

C. The Contractor will be permitted to submit reliability data previously acquired from similar equipment and subsystems for predicted reliabilities. If equipment selected is identical to equipment used within the existing Sound Transit operating system, the requirements herein can be waived upon written acceptance from the Resident Engineer. The contractor shall submit this request in writing with the specifics of the equipment and where used on the existing Sound Transit system.

D. Field reliability testing shall be on a subsystem basis with the subsystem as defined above. The Contractor shall initiate the field reliability testing at Substantial Completion. The testing duration shall be one year. If Chargeable Failures have accumulated to the extent that the requirements for MTBF for the sub-system cannot be met the demonstration period shall be extended in order to obtain the cycles/mean time between failure thresholds specified herein. In the event demonstration period extends beyond Acceptance the Sound Transit designated personnel shall maintain equipment and collect field reliability data. The Contractor shall coordinate data collection with Sound Transit personnel.
1.02 SUBMITTALS

A. Reliability Program.

1. Within 180 days after award of the Contract, submit for approval the proposed reliability program plan. The below elements of the program shall be based widely on industry accepted program such as, MIL-STD-785B and shall include, but not be limited to:

a.) Organization and responsibilities of the proposed reliability effort.

b.) Details of the design and component selection and screening processes proposed to be used to meet the reliability requirements.

c.) Details of the procedures proposed to be used to calculate MTBF predictions.

d.) Identification of the sources proposed to be used for component reliability data.

e.) Proposed serialized type forms and reports, including preventive maintenance and discrepancy reports specifically for the joint use of the Contractor and Sound Transit during the field reliability assessment-testing program.

2. State the accepted reliability program being followed and provide a conformance matrix between it and the above program elements.

B. Predicted Reliability Reports.

1. The Contractor shall submit the predicted reliability study 60 days prior to component procurement. The report shall provide the predicted reliability for each of the included subsystems and propose an alternate design or equipment for the approval of Sound Transit, if areas of common failure appear inherent in the specified design mode or equipment.

2. Update the reliability report and re-issue showing components that meet the reliability requirements. Indicate for each subsystem the estimated percent of design completion upon which the reliability prediction is made.

3. Include in the report, an analysis of items for which the prediction does not meet the reliability requirements or for which the prediction had changed significantly from the last report. Describe the corrective action proposed in this Section of the report for items predicted not to meet the reliability requirements.

4. Forward an updated report to Sound Transit whenever deviations of the predicted reliabilities are encountered during design (i.e., prior to production). If these reports indicate a marked decrease in predicted reliability, Sound Transit may require an alternate design or equipment change to increase predicted reliability to the requirements specified in the Table of Reliability Goals.

C. Reliability Testing Procedures.

1. Obtain Sound Transit approval of detailed test procedures before field reliability assessment testing begins. The test procedures shall include, but not be limited to, the following details:

a.) A listing of components by description, part number, and quantity comprising each line item in the Table of Reliability Goals.
b.) Graphical sample presentation of the test plan and table to be used.

c.) Burn-in (debugging) time.

d.) Performance parameters to be measured.

e.) Performance limits beyond which a failure has occurred.

f.) Sample report and log forms to be used.

1.03 DEFINITIONS

A. The following definitions apply specifically to terms used in this Section.

1. Mean Time Between Failure (MTBF): The average time that the subsystem will operate without a chargeable failure:

\[
MTBF = \frac{\text{operating time}}{\text{number of chargeable failures}}
\]

2. Minimum MTBF (MMTBF):

The value specified in the Table of Reliability Requirements by Sound Transit for minimum performance without rejection.

3. Chargeable Failure:

a.) All failures which require repair or replacement of contractor provided components or parts are chargeable unless specified otherwise herein, or unless determined by Sound Transit to be caused by a condition external to the equipment under test. Failure due to workmanship deficiencies shall be counted as chargeable. Transient failures when proven to be caused by a single condition shall be counted only as a single failure. Also, transient conditions which temporarily prevent a function from being successfully performed shall be counted as chargeable failures unless it is shown that they are the result of external influences beyond the requirements of this Specification. Non-Chargeable Failures.

b.) Failures which are proven to be the result of conditions exceeding those specified, (i.e., floods, derailments, vandalism, human error not normally protected against, etc.) shall be classed as non-chargeable and shall not be included in the reliability evaluation. Failure of parts installed or provided by others, i.e. network switches, existing fiber connections, PSERN radio base station, etc, that cause a dependent failure of a subsystem installed by the Contractor shall not be included in the reliability evaluation.

4. Failure Rate:

The reciprocal of MTBF. For this reliability assessment program, the failure rate is assumed to be constant throughout the life of the equipment.

5. Independent Failure:

A failure which will independently cause equipment performance outside of specified limits - one which occurs without being related to the failure of the associated items.
6. Dependent Failure:

A failure of a part which is a direct result of an independent failure - one which is caused by the failure of an associated item(s). Dependent failures are non-chargeable failures.

7. Simultaneous Failure:

An event in which simultaneous or multiple failures occur and each failed part will independently prevent satisfactory equipment performance. Such failure shall be counted as an equipment failure.

1.04 CONSTRUCTION OF TABLE OF RELIABILITY GOALS

The table of reliability goals includes: MTBF goals for components, which are to be demonstrated through submitted reliability information for the components concerned; MTBF goals for Systems as described in 1.05, are to be demonstrated through theoretical analysis and through Reliability Demonstration Testing of the systems as a whole.

1.05 MATERIALS INVOLVED IN RELIABILITY PROGRAM

A. The equipment considered part of each subsystem with requirements shall be as follows:

1. Emergency Telephone System

   a.) All telephone hardware (ETELs and PETs), software, power connections and wiring, and data/network hardware required to send and receive telephone signals and status data between the Control Center and the wayside or station device are required to meet the component MTBF for procurement and analysis purposes. Failure to transmit/receive voice or data between the Control Center and the wayside or station device is a System Chargeable Failure.

2. Public Address System

   a.) All public address system hardware, software, power connections and wiring, and data/network connections and wiring required to send and receive public address messages and data between the Control Center and the station speaker zone are required to meet the component MTBF for procurement and analysis purposes. Failure to transmit/receive voice or data between the Control Center workstations and more than one station speaker zone at one transit station is a System Chargeable Failure.

3. Closed Circuit Television System

   a.) All closed circuit television system hardware, software, power connections and wiring, and data/network connections and wiring required to send and receive data or images to the Control Center from the wayside or station device are required to meet the component MTBF for procurement and analysis purposes. Failure to transmit/receive data or images between the Control Center workstation and the wayside or station device is a System Chargeable Failure.

4. Radio System

   a.) All radio system hardware, software, power connections and wiring, and data/network connections and wiring required to send and receive voice or data signal from the
Control Center to the wayside. Failure to transmit/receive voice or data in the area required to be covered by the expanded radio system is a System Chargeable Failure.

5. SCADA - Train Control System

a.) All train control system hardware (office and field), software, power connections and wiring, and data/network connections and wiring required to send controls, receive indications, display train control information from the Control Center to the wayside or station. Failure to be able to perform these functions at a Control Center workstation is considered a Chargeable Failure.

6. SCADA - Emergency Ventilation System

a.) All Emergency Ventilation System hardware (office and field), software, power connections and wiring, and data/network connections and wiring required to send controls, receive indications, emergency ventilation information from the Control Center to the wayside or station. Failure to be able to perform these functions at a Control Center workstation is considered a Chargeable Failure.

PART 2 - PRODUCTS

The product of this Section consists of the documents that establish and verify the reliability goals have been met as specified.

PART 3 - EXECUTION

3.01 ASSESSMENT PROGRAM

A. Verification that the equipment fulfills the reliability requirements described herein shall be per the approved Reliability Plan and as prescribed herein.

3.02 FIELD RELIABILITY DEMONSTRATION TESTING

A. The reliability of the various equipment types and sub-systems is specified in the Table of Reliability Goals. The minimum mean time between failures must meet or exceed the reliability figures shown in the Table of Reliability Goals.

B. Test all designated equipment and subsystems.

C. Modify or replace any subsystem or component part rejected by the reliability assessment program without additional cost to the Contract. Any such modification or replacement shall be subject to the approval of Sound Transit and subjected to the same reliability assessment program as the original equipment.

D. Reliability tests shall start and end as described in this section. Data collection shall be per device; per subsystem; for each location with MTBF results cumulative.

3.03 TEST PREPARATIONS

A. The Contractor's personnel assigned to participate in field data collection for reliability testing shall be fully trained in their assigned tasks and be familiar with the approved reliability test plan. It is expected that these shall be the Contractor personnel assigned to maintain the Communications System until the Contractor's maintenance training class is completed.
B. The Contractor personnel assigned to evaluate reliability data, and supervise the overall execution of the Reliability Plan shall have performed a similar function for at least one prior major transit communications project.

3.04 ASSESSMENT REPORTS

Submit reliability assessment reports every three months showing comparison of field reliability testing results with accept-reject criteria for each subsystem item in the Table of Reliability Goals.

3.05 FINAL DOCUMENTATION

Submit a final reliability assessment report upon completion of specified reliability testing. The report shall be by device; by subsystem; by location and cumulative.

3.06 FAILURE DOCUMENTATION

A. Report and formally record any malfunction or fault which prevents or limits equipment from performing its function in accordance with these specifications. The report shall include:

1. Failure Rate.
2. Independent Failure.
3. Dependent Failure.
4. Simultaneous Failure.
5. Chargeable Failure
6. Non-chargeable Failure

3.07 PROCEDURE

A. Test Logs.

1. The logs shall contain the following information:

   a.) Identification of the component and subsystem by location, function, serial numbers (if applicable), and line item of Table of Reliability Goals to which the equipment is charged.

   b.) Number of like components and subsystems in service.

   c.) Date and time equipment was placed in service.

   d.) Date and time of each failure.

   e.) Cause of each failure.

   f.) Classification of each failure (chargeable, not chargeable).

   g.) All repairs and adjustments made and reasons for same.

   h.) Personnel name and signoff
2. Once each month, review the logs and make the following entries:

a.) Accumulated operating hours or cycles per subsystem.

b.) Accumulated chargeable failures per subsystem.

B. Preventive Maintenance.

1. Preventive maintenance procedures specified in the approved operating and maintenance manuals for the equipment during normal operation shall be performed during the reliability testing period. Any additional preventative maintenance during the period of the Contractor’s maintenance responsibility shall be recorded and evaluated for their effect on the reliability test.

2. Other maintenance actions required on behalf of other equipment such as troubleshooting, checkout, or downtime investigations shall be termed as preventive maintenance and classed as non-chargeable failures when performed in connection with reliability assessment.

C. Equipment Failure Record.

Maintain a failure record for each line item. The record shall be designed to permit keeping of the entire test history of each line item on a single sheet so that behavior of the line items may be easily recognized. This record shall show all component failures for the line item.

D. Verifying Repair.

Following repair or corrective action and prior to resumption of reliability testing, it shall be permissible to operate a maximum one week burn-in test to verify the effectiveness of the repair. Failures and repair time during this period shall be recorded and reported but not used in determining compliance with MTBF requirements.

E. Corrective Action.

When any reliability test reaches a reject decision, the test will be discontinued for that line item. Immediately notify Sound Transit. Develop and propose a plan for correction of the deficiencies. Sound Transit will review such corrective action and may require handling as a design change or modification.

F. Failure Summary Record.

Maintain a failure summary record containing all the information needed to reach an accept/reject decision on the system under test. Make all entries directly and there shall be no need to process the data prior to an accept/reject decision. The summary shall include all component failures considered chargeable on all like equipment under test. The record shall present the current test status, including information on the total hours of test, failures, and MTBF of all units on test.

3.08 MTBF EVALUATION CRITERIA

Acceptance or rejection shall be on an individual subsystem basis with the individual subsystems being the line items presented in the Table of Reliability Goals. Accept or reject decisions shall be based upon the procedures, formulae, and definitions specified herein. If test results fall short of the specified hours or cycles then the Contractor is required to propose a corrective action acceptable to Sound Transit that may include a redesign or selection of alternative equipment in
the subsystem if necessary. An extension of the reliability demonstration test shall then restart to prove the corrective action was sufficient.

### TABLE OF RELIABILITY GOALS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>MTBF Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a.</td>
<td>Emergency and Passenger Telephone Components</td>
<td>25,000</td>
</tr>
<tr>
<td>1b.</td>
<td>Emergency and Passenger Telephone System</td>
<td>560</td>
</tr>
<tr>
<td>2a.</td>
<td>Public Address Components</td>
<td>25,000</td>
</tr>
<tr>
<td>2b.</td>
<td>Public Address System</td>
<td>560</td>
</tr>
<tr>
<td>3a.</td>
<td>Closed Circuit Television Components</td>
<td>25,000</td>
</tr>
<tr>
<td>4b.</td>
<td>Closed Circuit Television System</td>
<td>2000</td>
</tr>
<tr>
<td>4.</td>
<td>Radio System</td>
<td>25,000</td>
</tr>
<tr>
<td>5.</td>
<td>SCADA -Train Control System</td>
<td>15,000</td>
</tr>
<tr>
<td>6.</td>
<td>SCADA – Emergency Ventilation System</td>
<td>15,000</td>
</tr>
</tbody>
</table>

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. This Section specifies clearing, grubbing, and disposing of vegetation, including bushes, brush, trees, stumps, roots, rubbish, refuse, trash, and debris within construction limits.
   B. This Section also specifies pruning of existing trees which overhang the track.

1.02 REFERENCES
   A. Definitions
      1. Clearing: Removing and disposing of all unwanted material from the surface.
      2. Grubbing: Removing and disposing of all unwanted vegetative matter from underground.

PART 2 - PRODUCTS

2.01 MATERIALS, EQUIPMENT, AND FACILITIES
   A. Materials, tools, equipment, and facilities shall be furnished for clearing and grubbing operations.

PART 3 - EXECUTION

3.01 GENERAL
   A. Notify the Resident Engineer prior to scheduled operations.
   B. Make work sites available to Sound Transit’s Archaeologist for observation, and notify the Resident Engineer when artifacts are discovered during operations.
   C. Clear and grub areas where operation will occur and areas for the Contractor’s convenience; restore areas with mulch, seeds, and plants as required.
   D. Protect survey markers, monuments, existing improvements, piezometers, observation wells, and adjacent properties from damage.
   E. Protect trees, lawns, and planted areas that are indicated to remain and are not in conflict with work shown on the Contract Drawings. Restore disturbed areas to their original conditions or better.
   F. Review with the Resident Engineer, the location, limits, and methods to be used before operations commence.
3.02 CLEARING AND GRUBBING

A. Clear and grub only within the limits indicated on the Contract Drawings. Unless otherwise indicated, clear and grub includes removal and disposal of roots, grass, and debris from the existing ground.

B. Remove stumps and roots completely in excavation areas and under embankments, where the original ground level is within 3-1/2 feet of subgrade or slope of embankments. Under embankment, where the original ground level is more than 3-1/2 feet below the subgrade or slope of embankment, cut off trees, stumps, and brush to within 6 inches of the ground.

C. Do not start earthwork operations in areas, where clearing and grubbing are not complete. Stumps and roots may be removed concurrently with excavation.

D. Protect and Prune Existing Trees:
   1. Pruning of existing trees shall be performed prior to commencing earthwork or trackwork construction. The Contractor shall prevent debris from tree pruning from falling on completed subgrade, ballast, or track or fouling ditches.
   2. Where "Protect and Prune Existing Trees" is indicated in the Contract Drawings, the Contractor shall trim tree branches that extend within 25 feet horizontally of the railroad track to attain a clear height of 26 feet over the rails. Contractor shall trim around the entire circumference of the tree, in order to prevent the tree from becoming unbalanced and in jeopardy of falling due to the unbalanced weight of un-pruned branches.
   3. Existing vegetation, where shown in the Contract Drawings, shall be saved and protected through the life of the Contract. The Resident Engineer will designate the vegetation to be saved and protected by a site preservation line, high visibility fencing, or individual flagging.
   4. Damage which may require replacement of vegetation includes bark stripping, broken branches, exposed root systems, cut root systems, poisoned root systems, compaction of surface soil and roots, puncture wounds, drastic reduction of surface roots or leaf canopy, changes in grade greater than 6 inches, or any other changes to the location that may jeopardize the survival or health of the vegetation to be preserved.
   5. When large roots of trees designated to be saved are exposed by the Contractor’s operation, they shall be wrapped with heavy burlap for protection and to prevent excessive drying. The burlap shall be kept moist and securely fastened until the roots are covered to finish grade. All burlap and fastening material shall be removed from the roots before covering. All roots 1-inch or smaller in diameter, which are damaged, shall be pruned with a sharp saw or pruning shear. Damaged, torn, or ripped bark shall be removed.

E. Where the work requires the placement of wood chip mulch, acceptable materials from clearing and grubbing may be used to produce such mulch.

3.03 DISPOSAL OF CLEARED AND GRUBBED MATERIALS

A. Cleared and grubbed materials shall become the Contractor’s property. Remove such materials from work site regularly, so their presence will not create hazardous conditions for workers and the public. Stockpile salvaged materials in a secured location.

B. Comply with Authority Having Jurisdiction requirements over handling, removal, hauling, and disposal of materials.
C. Do not burn or bury materials.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies excavation, subsurface extraction, subgrade preparation, backfill placement, and finish grading.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. American Society for Testing and Materials International (ASTM)
      d. ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³)
      e. ASTM D2216 Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
      f. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)
      g. ASTM D6938 Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
      h. ASTM D2974 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
      i. ASTM D3017 Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)
   2. Washington Administrative Code (WAC)
      a. WAC 296-155 Part N, Safety Standards for Construction Work, Excavation, Trenching and Shoring
   3. Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)
4. Standard plans and specifications of Authority Having Jurisdiction (AHJ)

B. Definitions

1. Excavation: Work involves earth moving and grading for the construction of buildings, bridges, landscaped areas, trackways, roadways, walkways, and other facilities.

2. Subsurface Extraction: Work involves removal of abandoned utilities, tanks, walls, foundations, and other below grade obstructions that interfere with the new construction. Work may also include the cleaning of such structures, if they are indicated on the Contract Drawings to be salvaged.

3. Structure Backfill: Work includes furnishing, placing, and compacting structural fill material around structures to the lines and grades indicated. Structural fill material includes borrow excavation and material.

4. Raising Grade Fill: Work includes furnishing, placing, and compacting of structural fill material on a subgrade to its new elevation indicated. Structural fill material includes borrow excavation and material.

1.03 SUBMITTALS

A. Materials sources, test results, such as moisture content and compactness, and certifications shall be submitted for approval and compliance with specifications.

B. If on-site material is proposed for use as any of the materials specified in construction, test results certifying suitability of the on-site material shall be submitted. Sampling and tests of the on-site material suitability shall be performed at a minimum of every 200 cubic yards of the material.

1.04 QUANTITY ASSURANCE

A. Quality Control and Quality Plan shall be provided.

B. Services of an approved independent soils testing laboratory shall be engaged to perform tests.

C. Tolerances:

1. Construct finished surfaces to plus or minus 1/2 inch of the elevations indicated in the Contract Documents.

2. Maintain the moisture content of fill material as it is being placed, within 2 percent of its recommended moisture content.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Material used (imported or native) for filling and backfilling construction shall meet the Contract Documents' requirements.

B. Inert, inorganic soil, free of deleterious substances, shall be used for fill and backfill. (Inorganic soil is soil containing less than three percent by dry weight of organic material when tested in accordance with ASTM D2974.) Fill and backfill shall be compact thoroughly without voids when watered and rolled.
C. Excavated on-site material may be considered suitable for fill, backfill, and embankment construction, if the material is free from organic matter and other deleterious substances and conforming to the requirements specified herein. Material shall be conditioned for reuse and properly stockpiled. Conditioning includes spreading material in layers less than or equal to 8 inches, and raking free of debris and rubble. Deleterious material and rocks exceeding 6 inches in largest dimension shall be removed from the site and disposed in accordance with Disposal of Surplus Material.

D. Materials for Trenching, Bedding, and Backfilling of utilities shall be in accordance with Section 31 23 33, Trenching and Backfilling for Utilities.

E. Material containing peat, muck, swampland, buried logs, stumps, or other contamination is deemed unsuitable for structural fill.

F. Material containing wood, organic waste, coal, charcoal, or other contamination is deemed unsuitable for non-structural fill.

G. For fill materials not specified on the Contract Drawings or Documents, Gravel Borrow conforming to WSDOT Standard Specifications, Section 9-03.14 shall be used.

H. Aggregates for crushed surfacing and roadway ballast shall comply with WSDOT Standard Specifications, Section 9-03.9.

I. The 3-way topsoil shall have a composition by volume as follows: 45-50 percent sandy loam, 35-40 percent organic amendment, and 10-15 percent peat with 100 percent passing through a 1/2 inch screen.

### 2.02 SOURCE QUALITY CONTROL

A. Fill and backfill materials proposed to be used for construction shall be verified and tested by approved Independent Testing Laboratory, for compliance with WSDOT Standard Specification, Section 9-03.20 and as follows:

1. Moisture-Density Relationship: ASTM D1557
2. Moisture Content: ASTM D2216
3. Liquid Limit: ASTM D4318
4. Plastic Limit and Plasticity Index: ASTM D4318
5. Percentage of Wear: ASTM C131 or C535 as applicable

B. Where classification of soils is necessary to meet specified requirements, laboratory tests shall be performed in accordance with ASTM D2487.

### PART 3 - EXECUTION

#### 3.01 EXAMINATION

A. Establish bench marks, grading stakes, and other markers as required.

B. Existing Utilities

1. Verify on site the location and depth (elevation) of existing utilities and services, before performing earth moving work. Perform work by hand, when excavating within 3 feet of an active utility line. Protect active utilities from potential damage
created by operation. Refer to Section 33 01 01, Maintenance of Existing Utilities, for additional requirements.

2. Remove abandoned utilities and plug ends, when encountered in during earth moving.

3. Report immediately the discovery of active utility lines, which are not indicated on the Contract Drawings, to the Resident Engineer and utility owners involved. Provide the Resident Engineer and utility owners free access to determine the measures deemed necessary to repair, relocate, or remove the utility.

3.02 PREPARATION

A. Provide erosion protection.

B. Clear and grub areas as indicated on the Contract Drawings.

C. Perform demolition as indicated on the Contract Drawings.

3.03 CONSTRUCTION

A. General Requirements

1. Provide dust control.

2. Provide erosion protection.

3. Regulate construction traffic by dispersing travel paths of construction equipment over the entire width of compacted surface, in order to achieve a uniform loading. Protect exposed soil layers with high moisture content from excessive wheel loads.

4. Do not excavate or remove from the project site or right-of-way any material, which is not within the designated excavation as indicated on the Contract Drawings, without written authorization from the Resident Engineer.

5. Excavate and remove materials outside the limits of the excavation, only if they are unstable and may potentially slide during operation. Maintain slopes and embankments until substantial completion and acceptance of the work.

6. Promptly repair slides, slipouts, washouts, settlements, and subsidence that occur for any reason, and refinish the slope or embankment to the indicated lines and grades.

7. Excavate and stockpile separately suitable fill and backfill material. Stockpile locations shall not create hazardous conditions for workers and the public.

8. Excess or unsuitable materials and debris shall become the Contractor's property. Remove and dispose such materials from the site in accordance with AHJ requirements. The Contractor is responsible for locating an approved disposal sites and haul routes.

B. Dewatering

1. Prevent surface and subsurface water from flowing into excavations and from flooding project site and its surrounding areas.

2. Provide and maintain pumps, sumps, suction and discharge lines, and other dewatering system components required to convey water away from excavations.
3. Establish and maintain temporary drainage ditches and other diversions to convey water away from excavations. Do not use trench excavations as temporary drainage ditches.

C. Moisture Control
1. Provide stormwater runoff control to intercept and convey stormwater away from the site. Eliminate standing water.
2. Apply uniformly water to surface, where subgrade or soil layer is to be moisture conditioned before compaction.
3. Remove and replace or air dry soil material that is too wet to compact to specified density. Soil material may be stockpiled or spread to dry.

D. Excavation
1. Perform excavation as indicated and required for footings, foundations, slab on grade, retaining walls, paving, and site grading. Work shall be done in compliance with requirements of WAC 296-155 Part N.
2. Trench and Excavate for utilities as indicated on Contract Drawings.
3. Excavate to the lines and grades as indicated on the Contract Drawings. Clear and level bottom of excavation; remove loose material, debris, and foreign matter.
4. Preserve material below and beyond the lines of excavations; where an excavation is carried beyond its limit, backfill with structural fill to the indicated grades.
5. Support and maintain stability of excavations by providing structural support, such as shoring, bracing, underpinning, and cribbing. Excavations may be maintained by sloping cut faces where space permits, and provided that the supporting calculations are sealed and signed by a civil engineer currently registered in the State of Washington. Calculations shall consider existing conditions, including adjacent traffic, construction loading, and other local effects.
6. Keep trenching widths to a minimum, allowing for space to install forms and as required by safety systems.
7. Place excavated material at least 3 feet away from excavation edge, to prevent cave-ins or bank slides.
8. Payment shall not be given for over-excavation caused by the Contractor's negligence or convenience.

E. Subsurface Extraction
1. Remove subsurface facilities and obstructions to the extent indicated.
2. When subsurface facilities or obstructions are encountered unexpectedly and they are interfering with new construction, notify the Resident Engineer promptly for corrective determination.

F. Subgrade Preparation
1. Prepare subgrade in accordance with WSDOT StandardSpecification, Section 2-06. Work may include for subgrade stabilization and protection.
G. Backfilling

1. Re-use material removed from excavations, if such material meets requirements.

2. Place backfill in layers no more than 8 inches of loose material, when heavy equipment is used for compaction. Place backfill in layers no more than 4 inches of loose material, when hand-operated tampers are used for compaction.

3. Place and compact backfill material in ways that the unbalanced horizontal loads will not be applied to the newly-placed structure or utility.

4. Backfill for utility trenches in accordance with Section 31 23 33, Trenching and Backfilling.

H. Compaction

1. Before compaction, moisten or aerate each layer as necessary to provide the optimum moisture content.

2. Compact each layer of fill, backfill, and embankment to specified compaction density. Compactions are defined as Class I and Class II.
   a. Class I Compaction: 90 percent relative compaction as determined by ASTM D1557.
   b. Class II Compaction: 95 percent relative compaction as determined by ASTM D1557.

3. Compact fill, backfill, and embankment where the finished surface will be a bearing foundation, to achieve Class II Compaction for full depth. However, where the embankment construction exceeds 5 feet in depth, provide minimum Class I Compaction below the top 2.5 feet.

4. Compact fill below pavements to achieve Class II for full depth. However, where the fill exceeds 3 feet in depth, provide minimum Class I Compaction below the top 3 feet.

5. Compact the top 12 inches of backfill around structures to achieve Class II Compaction, and material underneath to achieve Class I Compaction.

6. Compact the top 12 inches of cut-and-cover backfill to achieve Class II Compaction. Compact the 36 inches of backfill material above utility to achieve Class I Compaction.

7. Except for original ground, cut subgrade, or fill that is less than 1 foot thick, scarify the surface and compact the top 8 inches of material to achieve Class II Compaction, as well as meeting the following requirements:
   a. For original ground located within 2.5 feet of finished pavement, compact original ground to achieve Class II Compaction, for full width of pavement plus 3 feet on each side thereof.
   b. For original ground upon which embankment is to be constructed, compact the top 6 inches of material to achieve Class II Compaction.

8. Where not indicated on the Contract Drawings and structures are not involved, compact material to achieve Class I Compaction.

I. Finish Grading
1. Finish grading areas to elevations and slopes as indicated on Contract Drawings, within the specified tolerance.

2. In landscape areas, grade to depth required (below finished grade) to allow placement of topsoil or mulch as indicated on the Contract Drawings.

3.04 FIELD QUALITY CONTROL

A. Perform density tests on compacted fill, backfill, and embankment in accordance with ASTM D6938. Tests shall be frequently performed, not less than the following:
   1. Perform an initial test whenever material or source changes.
   2. For expansive horizontal areas, perform one test per 100 cubic yards maximum of fill or backfill placement.
   3. For confined areas and embankments, perform one test per every second lift of fill, backfill, or embankment placement.

B. Perform compaction tests on compacted fill, backfill, and embankment in accordance with ASTM D1557, Method D and ASTM D6938.

C. Perform moisture content tests on compacted fill, backfill, and embankment in accordance with ASTM D3017.

D. Maintain a clean and orderly work site.

END OF SECTION
SECTION 31 23 01
EXCAVATION SPOILS DISPOSAL

PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies requirements for excavation spoils management and disposal.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. Washington Administrative Code (WAC)
      a. WAC 173-350, Solid Waste Handling Standards

B. Definitions
   1. Adulterated: Added a non-native material, chemical, or substance to a native soil.
   2. Cementitious Materials: Materials containing cements, limes, mortars, grouts, or shotcrete.

1.03 SUBMITTALS
A. Excavation Spoils Management and Disposal Plan shall be submitted to the Resident Engineer. Plan shall include the following:
   1. Anticipated Waste Materials: Descriptions of waste material types, quantities, and their physical and chemical characteristics.
   2. Sampling and Testing: Descriptions of sampling and testing methods for excavation spoils prior to disposal.
   3. Soil Stabilization: Descriptions of physical or chemical treatment of excavation spoils, if necessary, prior to disposal.
   4. Waste Materials Handling Methods: For handling, stockpiling, testing, treating (if required), transporting, and disposing of waste materials
      a. Details for hauling waste materials shall include waste types, weighing method, name of the hauling Subcontractor, hauling method, equipment, round trip distances, hours, and the disposal facility for each waste material.
      b. Disposal site operator signed letters shall be provided, certifying that the site is licensed to receive the anticipated waste materials, and stating how many tons of each waste material the facility can receive daily. Copies of operational permits from the facility shall be included.
c. Information including contact name, address, e-mail address, telephone numbers, and operation hours and days for each disposal facility shall be provided. Any special arrangement made by the Contractor to deliver and dispose of waste material outside of facility’s regular operating hours shall also be indicated.

d. Disposal fees shall be provided in a table for each waste material type at each proposed disposal facility.

e. Contract with each proposed disposal facility shall include the acceptable criteria for each waste material and shall be provided.

B. Excavation Spoils Report shall be submitted cumulatively to the Resident Engineer for review on a monthly basis. Report shall include the following:

1. Record of type, quantity (by weight), physical characteristics, total transportation cost, and daily tipping fee of each excavation spoil and waste material disposed at each facility.

2. Copy of receipts, weight tickets, manifests, truck tickets, and fees issued by the disposal facility for each waste material.

3. Certification from each disposal facility owner that operating permit conditions are met.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 MEANS AND METHODS

A. Means and methods of handling, stockpiling, stabilizing, treating, transporting, and disposal of waste materials are exclusively determined and controlled by the Contractor; however, their employment shall minimize the disposal costs.

B. Cost impacts associated with the waste management, due to the means and methods of construction are the Contractor’s responsibility.

C. The final physical and chemical characteristics (such as water content and pH level) of the waste materials prior to disposal are determined by the Contractor’s means and methods.

1. The available geotechnical data and reports describe the physical and chemical characteristics of the undisturbed in-situ materials only; the reports do not characterize the waste material after it is disturbed by the Contractor.

D. Do not blend or cross contaminate waste materials.

E. Control stockpile runoff.

F. Use hauling equipment appropriate for containing and transporting waste materials with high water content (30 percent by volume). Trucks used for hauling high water content materials shall be equipped with tailgate locks and seals to prevent leakage along haul routes. Trucks shall utilize load-covering devices for hauling waste materials away from the Site.
3.02 PERMITS, REGULATIONS, AND LAWS

A. The Department of Ecology has determined that waste materials derived from cementitious materials and excavated soil, containing or affected by cementitious materials, are considered solid wastes under state law. Such waste materials shall follow the handling and disposing requirements of WAC Chapter 173-350. Any proposed recycling or re-use of such materials shall be approved and permitted in advance by the Department of Ecology.

B. Comply with Authority Having Jurisdiction regulations and laws governing the handling, transporting, and disposing of waste materials.

C. In case of disposing high pH (>8.5) waste materials, the Contractor shall confirm that the proposed disposal facility is licensed to receive high pH waste materials, and the facility is capable of containing and treating waste runoff.

D. When excavation spoils disposal is suspended at any time by any entity for any reason, within 24 hours, the Contractor shall submit reasons for suspension in writing to the Resident Engineer.

3.03 EXHIBITS

A. Exhibit A – Excavation Spoils Disposal Flow Chart

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Excavated spoils

Are spoils suspected to be contaminated as defined in Section 01 35 43.16?

Yes: Follow procedures in Section 01 35 43.16 and 02 61 13.

No: Do spoils contain cementitious materials or debris, or has it been physically or chemically adulterated by the construction processes?

Yes: Spoils are solid wastes and cannot be disposed as clean fill.

No: Spoils are clean fill and can be disposed properly.
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END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies trenching, excavating, and backfilling for utilities and related structures, which include underground piping, sewerage, electrical conduits, duct banks, catch basins, manholes, and vaults. Trenching and backfilling also encompasses restoration of existing pavement, where applicable, to its existing condition.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. Washington Administrative Code (WAC)
      a. WAC 296-155 Part N, Safety Standards for Construction Work, Excavation, Trenching and Shoring
   2. Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)
   3. Standard plans and specifications of Authority Having Jurisdiction (AHJ)

1.03 SUBMITTALS
A. Transmit materials sources, tests, and certifications. Test results shall include material moisture and density relation.
B. If on-site material is proposed for use as any of the materials specified in construction, test results certifying suitability of the on-site material shall be submitted. Sampling and tests of the on-site material suitability shall be performed at a minimum of every 200 cubic yards of the material, and shall also be performed randomly at the request of the Resident Engineer.
C. Drawings and calculations for trench excavations greater than 4 feet in depth shall be prepared, sealed, signed by a professional civil engineer registered in the State of Washington.

PART 2 - PRODUCTS

2.01 BEDDING AND BACKFILLING MATERIALS
A. Water line bedding and backfill materials
B. Sewer line bedding and backfill materials
C. Underground electrical, cable, and communication conduits:
   1. For conduits in areas that are or will be under sidewalk, bedding and subsequent backfill shall be crushed surface, in accordance with WSDOT Standard Specifications, Section 9-03.9(3) or AHJ.
2. For conduits in landscaped or unimproved areas, bedding and subsequent backfill shall be gravel borrow, in accordance with WSDOT Standard Specifications, Section 9-03.14(1) or AHJ.

D. Other utility lines bedding and backfill materials: See WSDOT Standard Specifications, Section 9-03.
   1. Pipe zone bedding and backfill material shall be in accordance with Section 9-03.12(3).
   2. Underdrain pipe zone bedding and backfill shall be in accordance with Section 9-03.12(4).
   3. Trench backfill materials shall be in accordance with Section 9-03.15 or 9-03.19.

E. Replace unsuitable or unstable materials with gravel foundation, in accordance with WSDOT Standard Specifications, Section 9-03.9(1).

F. The use of Controlled Density Fill (CDF) shall be in accordance with WSDOT Standard Specifications, Section 2-09.3(1)E.

PART 3 - EXECUTION

3.01 PREPARATION
   A. Establish bench marks, grading stakes, and other required markers.
   B. Verify on site the location and depth (elevation) of existing utilities and services, before performing earth moving work. Refer to Section 33 01 01, Maintenance of Existing Utilities, and Section 31 20 00, Earth Moving, for additional requirements.

3.02 CONSTRUCTION
   A. Trenching and Excavating
      1. Trench and excavate for utilities to the depths, lines, and grades indicated on the Contract Drawings and in accordance with AHJ standard. The maximum trench width in the Right of Way shall not exceed the neat line shown on Contract Drawings or value calculated based on WSDOT Standard Specifications, Section 2-09.4.
      2. In paved areas, sawcut pavement, curb, and sidewalk on the neat lines at the width indicated for the trench. Do not undermine or disturb pavements, sidewalks, and other adjacent facilities beyond the trench.
      3. Provide shoring, bracing, pumping, and planking in accordance with WAC 296-155, Part N. Protect the public, workers, and nearby facilities from damage caused by operation.
      4. Keep excavation length in advance of pipe installation operation to a minimum; excavation length shall not be greater than 200 ft.
      5. Excavate to the inverts plus any additional excavation required to accommodate the pipe barrels, pipe bells, and the bedding as shown on the Contract Drawings.
      6. If excavation width exceeds permissible dimensions, install higher strength pipe or encase the pipe in concrete, at no additional expense to Sound Transit.
7. If over-excavation is required, or material at the trench bottom is suspected to be unsuitable, notify the Resident Engineer.

8. Remove unexpected objects, such as stumps, log, railroad ties, and buried pavement, when they are encountered during the excavation. If the removal of unexpected objects requires an increase in trench size, or if the removal cannot be done by the equipment at hand, notify the Resident Engineer.

9. Dewater when water is encountered in the trench. Provide ballast or pea gravel to drain and stabilize trench bed.

10. Stockpile excavated materials.

11. After improvements to utilities are completed, backfill trench, safely remove trench protection without distributing compacted bedding, compact backfill, and restore pavement, curb, and sidewalk in accordance with AHJ requirements. Restoration outside the neat lines shall be done at no additional expense to Sound Transit.

B. Bedding and Backfilling

1. Place bedding and backfill for utilities as indicated on the Contract Drawings, in accordance with the applicable requirements of the utility owners.

2. Compact bedding prior to utilities placement. Provide uniform support along the utilities; eliminate load concentration at joint collars or bells. Do not use blocking to adjust utilities to grade.

3. Compact bedding disturbed by utilities placement or by trench protection removal prior to backfill.

4. Place backfill.

5. Re-use material removed from excavations, if such material meets the backfill requirements.

6. Unless otherwise indicated on the Contract Drawings, do not backfill structure until its required concrete component has reached the specified 28-day strength.

C. Compaction

1. Compact bedding and backfill.

D. Restoration

1. Restore surface as indicated on the Contract Drawings, in accordance with AHJ requirements.

3.03 FIELD QUALITY CONTROL

A. Refer to Section 31 20 00, Earth Moving, for quality control requirements.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies the material and construction requirements for the soil nail wall systems indicated on the Contract Drawings. This section also specifies requirements for any design modifications to be made to the wall systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Association of State Highway and Transportation Officials (AASHTO):
   a. AASHTO M111 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   c. AASHTO M291 Standard Specification for Carbon and Alloy Steel Nuts
   d. AASHTO Construction Specifications Section 11.3.3.1

2. American Concrete Institute (ACI):
   a. ACI 318 Building Code Requirements for Reinforced Concrete

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   c. ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, and Threaded Rod 60,000 PSI Tensile Strength
   d. ASTM A615 Standard Specification for Deformed and Plain Carbon Steel Bars for Concrete Reinforcement
   e. ASTM A722 Standard Specification for Uncoated High-Strength Steel Bar for Prestressed Concrete
   f. ASTM C33 Standard Specification for Concrete Aggregates
   h. ASTM C150 Standard Specification for Portland Cement
   i. ASTM D1248 Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

k. ASTM D3350 Standard Specification for Polyethylene Plastics Pipe and Fitting Materials

l. ASTM D 4716 Standard Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head


5. FWHW SA-96-069R Manual for the Design and Construction Monitoring of Soil Nail Walls

6. WSDOT Standard Specifications for Road, Bridge and Municipal Construction

1.03 DEFINITIONS

A. Closure Time: The duration of time between excavation to the neat line and the application of the shotcrete.

B. Drill Bench: Temporary bench created for purposes of installing soil nails.

C. Neat Line: Excavated surface corresponding to final wall excavation face limits as indicated on the Contract Drawings.

D. Soil Nail System: Excavation support system that occurs in staged lifts, consisting of soil nails and shotcrete lagging. The excavation in the vicinity of the wall requires special care and effort compared with general earthwork excavation.

E. GFRP: Glass fiber reinforced plastic.

F. Independent Geotechnical Engineer: Engineer selected by the contractor to monitor installation and testing of soil nails and to coordinate with the Resident Engineer.

1.04 TRANSMITTALS

A. Contractor Personnel Qualifications

B. Product Data: Manufacturer’s product data for manufactured products indicated.

C. Certifications

1.05 SUBMITTALS

A. Detailed Design Calculations and Plans if designed by the Contractor

B. Soil Nail Construction Work Plan

C. Soil Nail Test Results (including both Proof and Verification Test)

D. Soil Nail Installation Records

1.06 QUALITY ASSURANCE

A. If modifications are made to the soil nail system indicated on the Contract Drawings, provide calculations and drawings signed and stamped by a registered professional engineer licensed in the State of Washington.
B. Qualifications:

1. Contractor: Demonstrate completion of at least 3 soil nail retaining wall projects of similar size and complexity and in similar soil conditions in the past 3 years.

2. Onsite supervisors and drill operators: Demonstrate completion of at least 3 similar soil nail walls in similar soil conditions in the past 3 years.

3. Geotechnical Engineer: Select a licensed engineer with geotechnical background currently registered in the State of Washington, with a minimum of 5 years of experience in designing, monitoring and testing of soil nail excavation support systems.

C. Certifications:

1. Certified mill test for steel nail bars including chemical composition, ultimate strength, yield strength and elongation for each heat unit

2. Certified tests for GFRP nail bars including chemical composition, ultimate strength, and creep potential for each unit

3. Certified calibration records from an Independent Testing Laboratory for each test jack and pressure gage pair and load cell to be used: Include the following items on calibration records: device identification numbers, date tested, and calibration test results to be certified for accuracy within 2 percent of the applied loads.

4. Manufacturer certification for nail couplers and bar centralizers

1.07 SOIL NAIL CONSTRUCTION WORK PLAN

A. Design Calculations: If modifications are made to the soil nail system indicated on the Contract Drawings, provide calculations in accordance with design criteria specified herein.

B. Shop Drawings:

1. Consistent with layout indicated on the Contract Drawings

2. Indicate for each soil nail: Horizontal and vertical position, length, diameter, inclination, bar size and material, and splay angle.

3. Indicate locations of sheet drains, drain grates, and other appurtenances.

4. Indicate shotcrete thickness and reinforcement.

C. Site Drainage Plan: Address all elements necessary to divert, control, and dispose of surface and subsurface water during construction of the soil nail wall, coordinated with other requirements indicated. Control of surface water behind retaining walls may be accomplished by sloping to promote runoff away from the excavation, trenches and sumps, or shotcrete gutters. Grade the excavation to promote drainage away from the toe of the retaining walls.

D. Proposed Drilling Methods and Equipment: Including drill rig type, use of cased or open-hole methods, proposed drill hole diameter, and method of cuttings removal to achieve the specified pull-out resistance presented on approved submittals.

E. Methods for removing protrusions and backfilling voids, if required

F. Soil Nail Installation Details:
1. Nail grout mix design including: brand and type of portland cement and admixtures, quality and gradation of aggregates, proportion of mix by weight, water-cement ratio and compressive strength test result verifying the specified minimum 3 day and 28 day grout strength.

2. Nail grout placement procedures and equipment

3. Nail testing methods and equipment including: details of jacking frame and appurtenant bracing, methods of isolating test soil nails during shotcrete application, and methods of grouting the unbonded length of test nails after testing.

4. Identification of independent testing laboratory for soil nail testing

5. Bearing plates and nuts used

6. Corrosion protection details

7. Geocomposite sheet drain installation procedures

8. Shotcrete installation procedures as stated elsewhere in the Contract Documents

1.08 SOIL NAIL INSTALLATION AND TEST RECORDS

A. Installation records shall include:

1. Head location
2. Length and inclination of installed nail
3. Bar type and size
4. Soil conditions encountered during installation
5. Grout mix, pressure, and volume
6. Drill Hole Diameter

B. Test records shall include the information required for the installation records as well as the followings:

1. Bond Length, free length, and stressing length
2. Design bond strength
3. Testing procedures
4. Testing results

C. Installation and Test records shall be prepared by the independent Geotechnical Engineer and submitted to the Resident Engineer for approval.

1.09 DESIGN CRITERIA

A. If modifications are made to the soil nail system indicated on the Contract Drawings, revise design in accordance with the requirements herein.

B. Soil Nail System:

1. Design in accordance with DCM.
2. Be responsible for the stability of the interim temporary face cuts that exist prior to installation of the wall facing

C. Applicable Design Methods:
   1. SNAILZ
   2. GOLDNAIL
   3. Other methods if approved by Sound Transit.

D. Soil Parameters:
   1. For soil properties, refer to Geotechnical Baseline Report (GBR) and/or Geotechnical Data Report (GDR), if applicable. Baseline ground and groundwater conditions are established in the GBR. Boring logs, laboratory testing results, and geotechnical data are provided in the GDR.

E. Minimum Utility Clearance:
   1. Minimum Utility Clearance: 3 feet or distance required by entity with legal jurisdiction, whichever is greater
   2. Minimum Clearance between Soil Nails: Center-to-center clearance between soil nails shall be at least 1.5 feet for temporary soil nails and at least 2.5 feet for permanent soil nails. Center-to-center clearance between two parallel soil nails shall be at least 3 feet.
   3. If necessary, adjust inclination or splay angle of soil nails to meet clearance requirements.

F. Facing:
   1. For shotcrete Facing:
      b. Minimum thickness requirements: As indicated on the Contract Drawings.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Use construction materials for the soil nail walls that are new and without defect.

B. Shotcrete: Refer to sections stated elsewhere in the Contract Documents.

C. Soil Nail Grout: Neat or sand/cement mixture with:
   1. Cement: ASTM C150, Type II, Low Alkali
   3. Minimum 3 day compressive strength of 1500 pounds per square inch (psi)
4. Minimum 28-day compressive strength of 3000 pounds per square inch (psi)

5. Slump of 8 inches plus or minus 1 inch

D. Solid Nail Bars: Steel: Conform to ASTM A615, grade 75, or ASTM A722, grade 150. GFRP: See requirements for GFRP soil nail elements stated elsewhere in the Contract Documents.

E. Bar Couplers: Provide 125 percent of the full ultimate tensile strength of the steel bar as certified by the manufacturer. No splices are allowed with GFRP soil nail elements.

F. Headed Studs: Conform to ASTM A307, automatically end welded.

G. Bearing Plates: Conform to ASTM A36, grade 36.

H. Nuts and Washers: Conform to AASHTO M291, grade B, hexagonal-fitted, with beveled washer or spherical seat to provide uniform bearing.

I. Shear Connectors: AASHTO Construction Specifications, Section 11.3.3.1.

J. Corrosion Protection for Bars and Accessories: Provide corrosion protection for all steel soil nail bars and accessories.

1. Corrugated Plastic Sheathing for Nail Bars (Double Corrosion Protection):
   a. Polyvinyl chloride (PVC) or high-density polyethylene (HDPE)
   b. PVC: ASTM D1784 Class 13464-B.
   c. HDPE: ASTM D3350 Index No. 324420 C Table 1, ASTM D1248, and AASHTO M284.
   d. Minimum thickness of 0.04-inch for PVC or 0.06-inch for HDPE.
   e. Pre-grouted per manufacturer’s recommendations

2. Hot-Dip Galvanizing:
   a. Nail Bars per ASTM A123 or AASHTO M111.
   b. Accessories per ASTM A153

K. Bar Centralizers:

1. Schedule 40 polyvinyl chloride (PVC) material securely attached to the soil nail bar.

2. Size centralizers to position the soil nail bar within 1 inch of center of the drill hole, to allow tremie pipe insertion to the bottom of the drill hole, and to allow the grout to flow freely up the drill hole.

L. Geocomposite Sheet Drain:

1. Manufactured with a drainage core (i.e., geonet) and a drainage geotextile attached to or encapsulating the core. Drainage core with a minimum compressive strength of 15,000 pounds per square foot (psf) covered with filter fabric capable of maintaining drainage void.
2. The drainage core with the geotextile fully encapsulating the core shall have a minimum flow rate of 5 gallons per minute per foot width tested in accordance with ASTM D 4716.

2.02 EQUIPMENT

A. Drilling:
   1. Select drilling equipment and method suitable for anticipated ground conditions.
   2. In caving ground, use cased or augercast drilling methods to support the sides of the drill hole.

B. Grouting:
   1. Use a continuously agitating type mixer capable of producing a uniformly mixed grout, free of lumpy and undispersed cement. Select the size of the grout mixer to allow the full length of the soil nail to be grouted in one continuous operation.
   2. Use positive displacement grout pumps. Equip grout pump with a pressure gage that can measure at least twice, but no more than three times, the intended grout pressure.

C. Soil Nail Testing:
   1. Dial gages:
      a. A minimum of two dial gages capable of measuring to 0.001 inch available at the site to measure the soil nail movement
      b. Minimum travel sufficient to allow the test to be performed without resetting the gages
      c. Align the dial gages within 5 degrees of the axis of the soil nail and support independent of the jacking set-up and the wall.
   2. Jack with pressure gage:
      a. Calibrated as a unit by an Independent Testing Laboratory within the last 60 days
      b. Pressure gage graduated in 100 pounds per square inch increments or smaller
      c. Range for the pressure gage not more than twice the maximum anticipated pressure during the testing
      d. Ram travel for the jack is sufficient to enable the test to be performed without resetting the jack
      e. Capable of applying each increment load in less than one minute
   3. Load cell:
      a. In accordance with as stated elsewhere in Contract Documents
      b. Calibrated by an Independent Testing Laboratory within the last 60 days
   4. Reaction frame:
a. Sufficiently rigid and of adequate dimensions such that excessive deformation of the test apparatus requiring repositioning of any component does not occur during testing

b. Where the reaction frame bears directly on the shotcrete facing, design the reaction frame to prevent fracture of the shotcrete.

2.03 HANDLING AND STORAGE

A. Store cement to prevent moisture degradation and partial hydration. Discard cement that has become caked or lumpy.

B. Soil Nail Steel:

1. Keep soil nail bars free of dirt, rust, and other deleterious material prior to installation.

2. Handle soil nail bars in such a manner so as not to overstress the bar.

3. Damage to the soil nail bar because of overstressing, abrasion, cuts, nicks, welds, and weld splatter shall be cause for rejection by the Resident Engineer.

4. Grounding of welding leads to the soil nail steel is not allowed.

5. Heavy corrosion or pitting of soil nails shall be cause for rejection. Light rust that has not resulted in pitting is acceptable, subject to approval by the Resident Engineer.

6. Encapsulated nails shall not be transported until the encapsulation grout has reached sufficient strength to resist damage during handling.

C. Geocomposite Strip Drain:

1. Protect the fabric from mud, dirt, dust, debris, and shotcrete rebound.

2. Extended exposure to ultraviolet light shall be avoided.

PART 3 - EXECUTION

3.01 GENERAL

A. Sequence construction in accordance with the approved Soil Nail Construction Work Plan. Make no excavation steeper or higher than those specified on the approved Soil Nail Construction Work Plan above or below the soil nail wall without written authorization of the Resident Engineer.

B. Visit the site prior to starting construction activities for the purpose of observing and documenting the preconstruction condition of existing structures, sidewalks, roadways, and the other infrastructure within or adjacent to the work area.

C. The utilities referenced on the Contract Drawings are for informational purposes only. Field locate all utilities shown and not shown on the Contract Drawings prior to starting the work. Notify the Resident Engineer of utility conflicts, and seek approval to shift soil nail locations, if required.

D. Monitor the areas behind all the shoring walls as stated elsewhere in Contract Document. Notify Resident Engineer if new cracks develop in the existing structures. Limit vertical and horizontal movements as specified elsewhere in Contract Documents, and as indicated on the Contract Drawings. If the Resident Engineer determines that
movements exceed Action Levels, take all necessary corrective actions to stop the movement, and perform repairs to the impacted structures.

3.02 PREPARATION

A. Hold a readiness review meeting prior to the start of work to clarify the construction requirements for the work and to coordinate construction activities. Meeting shall be attended by: Sound Transit, the Resident Engineer, the Contractor, the approved Subcontractors for the excavation, soil nailing, and shotcreting and the Independent Geotechnical Engineer who will be observing the construction activities.

3.03 EXCAVATION

A. Excavation:

1. Do not excavate beneath a preceding shotcrete lift closer than 5 feet (horizontal) until:
   a. Nail grout and shotcrete on the preceding lift has reached 50 percent of their respective 28-day compressive strengths.
   b. Installation of connection hardware and soil nail testing for the preceding lift are complete and have been approved by the Resident Engineer.

B. Perform any excavation closer than 5 feet (horizontal) to the shotcrete face in accordance with the drill bench requirements described below and as shown on the approved Soil Nail Construction Work Plan.

1. During excavation of the drill bench for the next row of nails, maintain a bench to serve as a platform for the drilling equipment. Use the bench as a stabilizing berm against the final wall excavation face neat line.

2. Establish drill bench not more than 3 feet below the row of nails to be installed. Extend the bench out from the wall face a minimum distance to provide a safe working width for equipment and workers.

3. Immediately cease excavation if there is evidence either of ground movement such that soil nail wall is being adversely affected or of adjacent structures being damaged as a result of excavation. Take steps to stabilize the condition and notify the Resident Engineer immediately.

3.04 WALL EXCAVATION

A. Excavate to the neat line using procedures that:

1. Prevent ground loss.

2. Prevent swelling, air slaking or loosening of the soil face.

3. Minimize degradation of soil bearing support below the overlying portions of the soil nail wall and below the soil nails currently being installed.


5. Prevent ground freezing.

B. Do not excavate the ground beyond the neat line. Restore inadvertent over-excavation beyond the neat line using shotcrete as approved by the Resident Engineer.

C. Closure time:
1. Less than 8 hours or as approved by the Resident Engineer or:

2. As specified in the Contract drawings or Contract Special Provisions.

D. For extensions of the closure time for approval, construct a test cut and demonstrate for each anticipated soil type that the unsupported final excavation face wall is stable throughout the proposed closure time. Extensions of the closure time may be revoked by the Resident Engineer at any time depending on the performance of the cut face.

E. Boulders, cobbles or other intrusions that are encountered at the soil face are the responsibility of the Contractor. Construct shotcrete facing to the minimum specified thickness, and to the line and grade as shown on the Contract Drawings, regardless of such intrusions.

3.05 TEMPORARY END OF WALL CONDITIONS

A. Where the construction sequence results in discontinuous lifts along any soil nail row, extend the ends of the lifts beyond the end of next lower lift by at least 10 feet. Construct slopes or berms immediately beneath these stepped lifts to prevent sloughing or failure that would result in loss of face support provided by the slopes or berms.

3.06 DRILLING

A. Select drill hole diameter to provide the minimum specified grout cover over the soil nail bar and to develop the specified load carrying capacity presented in approved submittals.

B. Water, mud drilling, or any other fluids used to assist in cutting removal are not permitted for drill holes.

C. In caving ground, the Contractor shall use cased or augercast drilling methods to support the sides of the drill holes.

D. A licensed, Professional Land Surveyor shall locate all soil nails prior to drilling.

E. Immediately cease drilling operations if there is evidence either of ground movement such that soil nail wall is being adversely affected or of adjacent structures being damaged as a result of drilling operations. Take steps to stabilize the condition and notify the Resident Engineer immediately.

3.07 SOIL NAIL BAR INSTALLATION

A. Install soil nails prior to the application of shotcrete at the location and to the length indicated on the approved Soil Nail Construction Work Plan, and in accordance with the Contract Drawings. Remove bars that cannot be easily inserted to their full design length. After the drill holes have been cleaned sufficiently to allow unobstructed installation of the bar, reinstall bars.

B. Centralizers are required for all soil nail bars, including bars installed using cased and augercast methods.

3.08 GROUTING

A. Grout equipment shall produce a uniformly mixed grout free of lumpy and undispersed cement. A positive displacement grout pump shall be used. The grouting equipment shall be sized to enable to entire nail to be grouted in one continuous operation. The mixer shall be capable of continuously agitating the grout during usage.

B. Leave no drill hole open for more than one hour prior to grouting. Grout drill hole after the installation of the soil nail bar. Grouting prior to the installation of the soil nail bar may be allowed upon demonstration, to the satisfaction of the Resident Engineer, that
insertion of the soil nail bar can be achieved without difficulty after the grouting. If the Resident Engineer allows grouting prior to insertion of the soil nail bar, use neat cement grout.

C. Inject grout at the lowest point of each drill hole through a tremie pipe casing, hollow stem auger, or drill rods. Fill drill hole in one, continuous operation. Keep end of conduit that delivers the grout below the surface of grout as the conduit is withdrawn. Withdraw grouting conduit in a manner to prevent the creation of voids.

D. If the grouting of any nail is suspended for more than 30 minutes or if the quality of the grout placement results in a nail that does not satisfy the requirements of this specification, the steel and grout shall be removed from the hole, disposed of, and replaced with fresh grout and undamaged steel.

3.09 WALL DRAINAGE

A. Install drainage matting as shown on the Drawings. Secure drainage matting to the face of the excavation with the geotextile/fabric side against the ground surface.

B. Splicing of the prefabricated drainage mat shall be in accordance with the manufacturer’s recommendations. The Contractor shall ensure the hydraulic connection of the drainage mat to the previously installed material so that the vertical flow of water is not impeded. Connect weep pipes to the drainage matting per the manufacturer’s recommendations. Seal the weep pipe during application of shotcrete to prevent shotcrete intrusion. Remove the seal after application of shotcrete.

C. Weep pipes shall be flush to the finished face of temporary walls. At walls with permanent soil nails, the weep pipes shall extend at least four inches beyond the exposed face of shotcrete lagging.

3.10 GROUT TESTING

A. Test the nail grout in accordance with ASTM C109 at a frequency of no less than one test per every 50 cubic yards of grout placed, or once every week, whichever comes first.

3.11 SOIL NAIL TESTING

A. Perform verification and proof tests at locations selected by the Independent Geotechnical Engineer and approved by the Resident Engineer. Perform soil nail pull-out tests when grout reaches at least 50 percent of its specified 28-day compressive strength.

B. Tests shall be witnessed and documented by the Independent Geotechnical Engineer. Submit results of all testing to the Resident Engineer.

C. When temporary casing of the unbonded length of test nails is provided, install the casing to prevent any reaction between the casing and the grout bond length of the soil nail and the stressing apparatus.

D. Independently support the jack and center over the soil nail so that the nail does not carry the weight of the jack. Place the stressing equipment over the soil nail in such a manner that the jack, bearing plate, and the stressing anchorage are in alignment. Position the jack at the beginning of the test such that unloading and repositioning of jack during the test will not be required.

3.12 TEST SOIL NAIL UNBONDED LENGTH

A. Provide temporary unbonded lengths for each test soil nail. Isolate test soil nail bar from shotcrete facing and the reaction frame during testing. Isolation of the test soil nail
through the shotcrete facing shall not affect the location of the reinforcing steel under the bearing plate. Accepted proof test nails may be incorporated in the work provided the temporary test unbonded length is fully grouted subsequent to testing.

3.13 VERIFICATION TESTING

A. Perform two verification tests in each anticipated major soil strata prior to installation of production nails to verify installation methods, soil nail pullout capacity, and design assumptions in accordance with FHWA requirements. The soil nails used for the verification tests will be sacrificial. Do not incorporate these soil nails into the production soil nails.

B. Construct verification test soil nails using the same methods and hole diameter as planned for the production soil nails. Additional verification testing is required for all changes in drilling equipment or installation methods. Provide additional verification testing at no additional cost to Sound Transit.

C. The jack shall be independently supported and centered over the nail so that the nail does not carry the weight of the jack. The jack shall be positioned at the beginning of the test such that unloading and repositioning of the jack during the test will not be required.

D. A minimum of two dial gauges capable of measuring to 0.001 inch shall be available at the site to measure the nail movement. The dial gauges shall have a minimum travel sufficient to allow the test to be performed without re-setting the dial gauge. The gauges shall be aligned within 5 degrees of the axial of the nail and shall be supported independent of the jacking set-up and the wall. The nail loads during verification tests shall be monitored with both a pressure gauge and electric load cell.

E. Use an unbonded length of the test soil nail of at least 3 feet within the drill hole unless approved otherwise. The unbonded length must extend from the back of the bearing plate to the top of the bonded length. Determine the bonded length of the soil nail based on grade and size such that the allowable bar load is not exceeded based on FHWA-NHI-14-007; however, do not use lengths less than 10 feet. Do not exceed an allowable bar load during testing of 80 percent of the steel ultimate yield strength for grade 150 bars, or 90 percent of the yield strength for grade 75 or grade 60 bars. For GFRP bars do not exceed 50 percent of the ultimate strength of the bar during testing.

F. Determine the Verification Test Load (VTL) by multiplying the bond length of the nail by the applicable nominal pullout resistance as shown on the Contract Drawings.

G. During Verification testing, incrementally load test soil nails in accordance with the following schedule:
### 3.14 PROOF TESTING

A. Perform proof testing on approximately 5 percent of the production soil nails in each shotcrete lift, or one nail per row, whichever is greater.

B. Proof tests are single-cycle tests in which the load is applied in increments to a maximum proof test load (PTL).

C. The maximum load in the proof test is the bonded length times the nominal pullout resistance (per unit length) x 0.75.

D. Proof tests are conducted according to the following loading schedule:

<table>
<thead>
<tr>
<th>Load</th>
<th>Hold Time (minutes)[3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment Load (AL)</td>
<td>1</td>
</tr>
<tr>
<td>0.17 PTL</td>
<td>Until Movement Stabilizes [4]</td>
</tr>
<tr>
<td>0.33 PTL</td>
<td>Until Movement Stabilizes</td>
</tr>
<tr>
<td>0.50 PTL</td>
<td>Until Movement Stabilizes</td>
</tr>
<tr>
<td>0.67 PTL</td>
<td>Until Movement Stabilizes</td>
</tr>
<tr>
<td>0.83 PTL</td>
<td>Until Movement Stabilizes</td>
</tr>
<tr>
<td>1.00 PTL (Creep Test) [2]</td>
<td>10 recorded at 1, 2, 4, 5, 6, and 10</td>
</tr>
<tr>
<td>AL</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: [1] AL = alignment load should be less than 0.025 PTL.

[2] If the nail movement measured between 1 and 10 minutes exceeds 0.04 inch, PTL must be maintained for 50 additional minutes and movements must be recorded at 20, 30, 50 and 60 minutes. The permanent soil movement must also be recorded.
[3] Times are measured after the target load has been achieved in each increment.

[4] If the soils reinforced with nails are relatively susceptible to deformation of creep, it is recommended to hold each load increment for 10 minutes and to record the soil nail movement at 1, 2, 5, and 10 minutes.

E. At the Contractor’s option, successful proof test nails meeting the acceptance criteria may be incorporated as production nails, provided that (1) the unbonded test length of the nail hole has not collapsed during testing, (2) the minimum required hole diameter has been maintained, and (3) the test nail length and bar size are equal to or greater than the scheduled production nail length and bar size. Grout the unbonded nail length for test soil nails meeting these requirements.

3.15 TEST NAIL ACCEPTANCE CRITERIA

A. Test nails will be considered acceptable when:

1. For verification tests, a creep rate less than 0.04 inch per log cycle between the 1- and 10-minute readings at 0.75 VTL, a creep rate less than 0.08 inch per log cycle of time between the 6-and 60-minute readings at 0.75 VTL is observed, and the rate is linear or decreasing throughout the creep test load hold period.

2. For proof tests, a creep test rate less than 0.04 inch per log cycle of time between the 1- and 10-minute readings is observed. If this is exceeded, the creep test should be extended so that a creep rate less than 0.08 inch per log cycle of time between the 6- and 60-minute readings is achieved, and the creep rate is linear or decreasing throughout the creep test load hold period.

3. The total movement at the maximum test load exceeds 80 percent of the theoretical elastic elongation of the test nail unbonded length.

4. A pullout failure does not occur during testing. Pullout failure is defined as the load at which attempts to increase the test load result in continued pullout movement of the test nail.

3.16 INADEQUATE SOIL NAIL PERFORMANCE

A. The Resident Engineer will evaluate the results of each verification test. Installation methods that do not result in satisfactory testing results will be considered inadequate. Propose alternate methods and perform additional replacement verification tests if the installation methods are deemed inadequate. Install replacement test soil nails and test at no extra cost to Sound Transit.

B. The Resident Engineer will evaluate the results of each proof test. The Resident Engineer may require that the Contractor replace some or all of the production soil nails represented by an inadequate proof test soil nail. Alternatively, the Resident Engineer may require additional proof test soil nails to be installed and tested to verify the adequacy of the previously installed soil nails. The cost associated with installing and testing of additional test soil nails as a result of poor test nail performance will be the responsibility of the Contractor unless otherwise determined by the Resident Engineer to be due to causes beyond the Contractor’s control.

3.17 SOIL NAIL TOLERANCE

A. Do not extend soil nails beyond indicated right-of-way or easement limits, unless approved otherwise by the Resident Engineer and Sound Transit.

B. Center bars within 1 inch of the center of the drill hole.

C. Position individual soil nails at the locations shown on approved Soil Nail System Plan.
D. Install nails at a nail splay angle of plus or minus 3 degrees of angle shown on approved submittals, unless clearances to utilities will be less than minimum values.

E. Relocate nails that encounter unanticipated obstructions, or remove obstructions.

F. Replace nails that do not meet the tolerance criteria due to construction methods.

3.18 SOIL NAIL INSTALLATION RECORD

A. Document and maintain accurate records of the soil nail wall construction. Include soil nail locations, top of wall elevations, and other information requested by Sound Transit.

3.19 FACING INSTALLATION

A. Install shotcrete facing as indicated on the Contract Drawings, and conforming to requirements as stated elsewhere in Contract Documents.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing all materials, labor, tools, equipment, services, and incidentals necessary to construct drilled shaft foundations in accordance with the Contract Drawings.

1.02 REFERENCES

A. This Section incorporates by reference the latest revision of the following documents:

1. American Association of State Highway and Transportation Officials (AASHTO)
2. American Concrete Institute (ACI)
3. American Society for Testing and Materials International (ASTM)
4. American Welding Society (AWS)
5. American Petroleum Institute (API)
   a. API RP 13B-1 Recommended Practice for Field Testing Water Based Drilling Fluids
6. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge and Municipal Construction

1.03 DEFINITIONS

A. Disturbed Soil: Soil whose geotechnical properties have been changed from those of the original in-situ soil, and whose altered condition adversely affects the structural integrity of the shaft foundation.

B. Obstruction: A specific object which significantly reduces the rate of drilling relative to the rate of advance of the drilling for the rest in the geological unit containing the obstruction. Logs and timber piling will not be considered obstructions.

C. Open Shaft Excavation: A shaft excavation that has not been filled with concrete or temporarily backfilled.

D. Pause: A momentary interruption of the drilling operation to splice casing, change tools, maintain slurry, or remove obstructions.

E. Permanent Casing: Casing designed as part of the shaft structure and to remain in place after construction is complete.

F. Stop: A momentary interruption of the drilling operation not conforming to the definition of a pause.
G. Temporary Casing: Casing installed only to facilitate shaft construction, and to be removed completely after construction is complete, unless otherwise shown in the Contract Drawings.

1.04 TRANSMITTALS

A. Qualifications: Submit qualifications for the following demonstrating conformance:
   1. Drilled Shaft Construction Contractor
   2. On-site supervisors
   3. Drill rig operators
   4. Personnel performing non-destructive testing
   5. Welders

B. Synthetic Slurry
   1. When synthetic slurry is used, keep a written record of all additives and concentrations of the additives in the synthetic slurry. Transmit these records to the Resident Engineer once the slurry system has been established in the first drilled shaft on the project.

C. Synthetic Slurry Technical Assistance
   1. If synthetic slurry is used to construct the shafts, provide or arrange for technical assistance in the use of the synthetic slurry. Transmit one of the following to the Resident Engineer for record:
      a. The name and current phone number of the synthetic slurry manufacturer's technical representative assigned to the project.
      b. The name(s) of the Contractor's personnel assigned to the project and trained by the synthetic slurry manufacturer in the proper use of the synthetic slurry. The submittal shall include a signed training certification letter from the synthetic slurry manufacturer for each trained Contractor's employee listed, including the date of the training.

1.05 SUBMITTALS

A. Concrete Mix Designs: Section 03 05 15, Portland Cement Concrete.

B. Concrete Reinforcing: Section 03 20 00, Concrete Reinforcing. Include bracing and any extra reinforcing steel required for fabrication, transportation, and installation; and details of the proposed reinforcing cage spacers.

C. Shop Drawings for Permanent Casings

D. Construction Work Plan (CWP): Submit a CWP providing at least the following information:
   1. An overall construction operation sequence and the sequence of drilled shaft construction. Reference the available subsurface data provided in the contract test hole boring logs and the geotechnical report.
   2. Description and capacities of proposed equipment, including but not limited to cranes, drills, auger, bailing buckets, final cleaning equipment, and drilling unit. Describe its suitability to the anticipated site and subsurface conditions. Include
a project history of the equipment demonstrating the successful use on shafts of equal or greater size in similar site and subsurface conditions.

3. Description of shaft excavation methods, including proposed drilling methods, methods for cleanout of the shafts, and a disposal plan for excavated material and drilling slurry (if applicable). Include a review of method suitability to the anticipated site and subsurface conditions.

4. Description of the methods to be used to ensure shaft stability (i.e., prevention of caving, bottom heave, etc. using temporary casing, slurry, or other means) during drilling and concrete placement. Include provisions for pauses and stops in drilling. Include a review of suitability to the anticipated site and subsurface conditions. If temporary casings are proposed or required, provide casing dimensions and procedures for installation and removal.

5. Procedures for mixing, installing, maintaining, and disposing of the slurry (if applicable). Provide a detailed mix design and a discussion of its suitability to the anticipated subsurface conditions for the proposed slurry.

6. Plan for quality control of the selected slurry, including tests to be performed, test methods to be used, and minimum and/or maximum property requirements that shall be met to ensure that the slurry functions as intended, considering the anticipated subsurface conditions and shaft construction methods, in accordance with the slurry manufacturer's recommendations. As a minimum, include the following tests:
   a. Density: Mud Weight (Density), API RP 13B-1
   b. Viscosity: Marsh Funnel and Cup, API RP 13B-1
   c. pH: Glass electrode, pH meter or pH paper
   d. Sand Content: Sand, API RP 13B-1

7. Description of method used to fill or eliminate all voids below the top of shaft between the plan shaft diameter and excavated shaft diameter.

8. Description of reinforcement placement. Include bracing, centering, and lifting methods, and the method to ensure the reinforcing cage position is maintained during construction.

9. Description of concrete placement. Include proposed pumping and/or tremie methods, and a sample uniform yield form to plot the volume of concrete place versus the depth of shaft.

10. Description of the methods used to construct the column, and the portion of the shaft above the upper construction joint and below existing ground.

11. Description of emergency horizontal construction joint during concrete placement.

12. Description of the device used to prevent unauthorized entry into a shaft excavation.

13. Description of the methods used to temporarily backfill a shaft excavation during a stoppage. Include backfill material used as well as the methods to place and remove the material.

14. Description of shaft vibration monitoring plan to the Resident Engineer for approval, including a description of the monitoring equipment, and the installation
and monitoring procedure. The monitoring equipment shall be sensitive enough to detect a Peak Particle velocity of 1/4 inch per second.

1.06 QUALITY ASSURANCE
A. Qualifications
1. Drilled Shaft Construction Contractor: Successful completion of at least three (3) separate bridge drilled shaft foundations projects within the past five (5) years with drilled shafts equal to or larger than those shown in the Contract Drawings with similar site and subgrade conditions. Include contact information for the project owner’s representative.

2. On-Site Supervisors: A minimum two (2) years of experience in supervising construction of drilled shaft foundations with similar site and subgrade conditions.

3. Drill Rig Operators: A minimum one (1) year of experience in construction of drilled shaft foundations.

4. Non-Destructive Testing
   a. Organization: A minimum of three (3) drilled shaft foundation projects in the last two (2) years.
   b. Personnel: A minimum of two (2) years of experience in crosshole sonic log testing and interpretation.
   c. The Resident Engineer may suspend the drilled shaft construction if the Contractor substitutes unqualified personnel.

B. Shaft Construction Tolerances:
1. Construct drilled shafts such that the center at the top of the shaft is within the following horizontal tolerances:
   a. Diameter less than or equal to 2 feet: 3 inches
   b. Diameter greater than 2 feet and less than 5 feet: 4 inches
   c. Diameter 5 feet and greater: 6 inches

2. Install shafts within 1.5 percent of plumb.

C. Reinforcing Placement Tolerances:
1. Top of reinforcing cage: plus 6 inches, minus 3 inches
2. Spacing of bend and ends of bars: plus or minus 1 inch
3. Length of bar laps: minus 1 ½ inch

D. Shaft Vibration Monitoring: Provide and operate monitoring equipment able to detect a peak particle velocity of 1/4 inch per second.

E. Nondestructive Testing of Shafts
1. Provide access tubes.
2. Perform crosshole sonic log testing of specific shafts

F. Preconstruction Conference
1. If synthetic slurry is used to construct the shafts, discuss the frequency of scheduled site visits by the manufacturer’s representative. The list of materials specified in the Record of Materials (ROM) form for this item of work will also be discussed. Those attending shall include:

a. The superintendent on-site supervisors, and all foremen in charge of excavating the shaft, placing the casing and slurry as applicable, placing the steel reinforcing bars, and placing the concrete. If synthetic slurry is used to construct the shafts, the slurry manufacturer’s representative and the Contractor’s employee trained in the use of the synthetic slurry shall also attend.

b. The Resident Engineer and key inspection and design personnel.

2. If the Contractor’s key personnel change, or if the Contractor proposes a significant revision of the approved shaft installation plan, an additional conference shall be held before any additional shaft construction operations are performed.

1.07 SEQUENCING AND SCHEDULING

A. Schedule drilling or excavating, installation of reinforcing steel and concrete placement so that each excavated shaft is placed immediately after drilling or other excavating is complete and reinforcing steel is placed.

B. Provide means to prevent heavy vibration or excessive wheel loads within the immediate vicinity of shaft excavation. Maintain stable excavation at all times.

PART 2 - PRODUCTS

2.01 TEMPORARY AND PERMANENT CASING

A. Furnish temporary and permanent casing in accordance with the contract drawings.

B. Furnish all casing to be watertight and clean prior to placement in the excavation.

C. The outside diameter of the casing shall not be less than the specified diameter of the shaft. The inside diameter of the casing shall not be greater than the specified diameter of the shaft plus 6 inches, except as otherwise noted for drilled shafts 5 feet or less in diameter. The inside diameter of casing for drilled shafts 5 feet or less in diameter shall not be greater than the specified diameter of the drilled shaft plus 1 foot.

D. Smooth wall structure of steel base metal. All casing shall be of ample strength to resist damage and deformation from transportation and handling, installation and extraction stresses, and all pressures and forces acting on the casing. The casing shall be capable of being removed without damaging the casing, deforming or damaging the completed shaft, and without disturbing the surrounding soil.

2.02 SLURRY (IF APPLICABLE)

A. Mineral Slurry: Mineral slurry shall not be used.

B. Synthetic Slurry: Acceptable products:

1. Novagel, by Geo-Tech Services, LLC

2. ShorePac GCV, by CETCO
3. SlurryPro CDP, by KB International, LLC.
4. SuperMud, by PDS Company (liquid product only)
5. Provide synthetic slurry with the following properties.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (pcf)</td>
<td>Mud Weight (Density), API 13B-1, Section 1</td>
<td>64 maximum</td>
</tr>
<tr>
<td>Viscosity (sec./quart)</td>
<td>Marsh Funnel and Cup, API 13B-1, Section 2-2</td>
<td>32 - 135</td>
</tr>
<tr>
<td>pH</td>
<td>Glass electrode, pH Meter</td>
<td>6 – 11.5</td>
</tr>
<tr>
<td>Sand Content (percent) before final cleaning and immediately before placing concrete</td>
<td>Sand, API RP 13b-1</td>
<td>1.0 maximum</td>
</tr>
</tbody>
</table>

C. Water Slurry (with or without site soils)
   1. Water with or without site soils may be used as slurry when casing is used for the entire length of the drilled hole. Use of water slurry without full-length casing may only be used with the approval of the Resident Engineer.

   Provide water slurry with the following properties in conformance with API RP 13B-1. Slurry temperature shall be at least 40 degrees Fahrenheit when tested.

<table>
<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (pcf)</td>
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</tr>
<tr>
<td>Sand Content (percent) before final cleaning and immediately before placing concrete</td>
<td>Sand, API RP 13B-1</td>
<td>1.0 max.</td>
</tr>
</tbody>
</table>

2.03 ACCESS TUBES FOR CROSSHOLE SONIC LOG TESTING

A. Steel pipe (Schedule 40) with minimum 0.145 inch wall thickness and minimum 1-1/2 inch inside diameter.

B. One access tube shall be furnished and installed for each foot of shaft diameter, rounded to the nearest whole number. The total number of access tubes shall not be less than 4.

C. Round, regular inside diameter free of defects and obstructions (loose rust, scale, dirt, paint, oil and other foreign material), including all pipe joints, able to permit the free, unobstructed passage of 1.3-inch maximum diameter source and receiver probes.

D. Watertight, free from corrosion with clean internal and external faces to ensure good bond between concrete and tubes. Fit tubes with watertight caps on the bottom and the top.
2.04 REINFORCING STEEL
   A. Conform to the concrete reinforcing in Section 03 20 00.

2.05 CONCRETE MATERIAL
   A. Conform to the Portland cement concrete materials in Section 03 05 15.

2.06 GROUT
   A. For sealing access tubes: Neat cement with a maximum water/cement ratio of 0.45.

PART 3 - EXECUTION

3.01 SHAFT EXCAVATION
   A. During shaft excavation, make frequent checks on the plumbness, alignment, and dimensions of the shaft. All deviations exceeding the allowable tolerances shall be corrected with a procedure approved by the Resident Engineer.

   B. Once started, conduct the shaft excavation in a continuous operation until excavation of the shaft is completed, except for pauses and stops as noted.

   C. Pauses: Pauses during excavation except for casing splicing, tooling changes, slurry maintenance, and removal of obstructions, will not be allowed.

   D. Stops: Stops for uncased or partially cased excavations shall not exceed 16 hours. Stops for fully cased excavations shall not exceed 65 hours. For stops exceeding the times stated above, stabilize the excavation with one or both of the following:
      1. Install casing to the depth of the excavation. Prior to removing the casing and resuming excavation, sound the annular space between the casing and the excavation. If the sounding indicates that caving has occurred, do not remove the casing. Stabilize the excavation in conformance with the approved CWP before resuming drilling.
      2. Backfill the excavation in conformance with the approved CWP. Backfill to the ground surface if the excavation is not cased, or to a minimum of 5 feet above the bottom of casing if the excavation is cased.

   If slurry is used, maintain the minimum level of slurry and slurry properties during the stop. During stops, stabilize the shaft excavation to prevent bottom heave, caving, head loss, and loss of ground.

   E. Do not leave excavations open overnight unless cased full depth.

   F. Do not operate drilling equipment from an existing bridge, unless approved by the Resident Engineer.

   G. Use appropriate means such as a cleanout bucket or air lift to clean the bottom of the excavation of all shafts. No more than 2 inches of loose or disturbed material shall be present at the bottom of the shaft.

   H. Allow the Resident Engineer to inspect the shaft before proceeding with construction. The bottom of the excavated shaft will be sounded with an airlift pipe, a tape with a heavy weight, or other means acceptable to the Resident Engineer.
3.02 TEMPORARY CASING

A. Provide temporary casing if required to maintain a stable excavation and facilitate construction. Provide in sufficient quantities to meet the needs of the anticipated construction method.

B. Ensure casing is watertight and clean before placement in the excavation.

C. Advance casing prior to or concurrently with excavation. Do not advance excavation ahead of casing tip at any time.

D. Install and remove temporary casing such that the adjacent soil outside the casing and shaft excavation for the full height of the shaft is not disturbed.

3.03 UNEXPECTED REMOVAL OF STRUCTURES OR OBSTRUCTIONS FOR DRILLED SHAFTS

A. The Contractor shall immediately notify the Resident Engineer upon discovery and before the conditions are further disturbed, verbally and in writing of a structure or obstruction (a specific object including boulders, logs and manmade objects) encountered during a drilled shaft operation that prevents advancement of a drilled shaft and is not otherwise identified in the Contract documents.

B. Shallow structures or obstructions shall be removed without additional compensation. Shallow structures or obstructions are located within 5 feet of the surface of the excavated ground prior to drilling or as otherwise identified in the Contract documents.

C. The Resident Engineer will be sole judge of the determination and significance of any unexpected structures or obstructions and the classification of the specific object.

D. The Contractor shall remove all structures or obstructions encountered at drilled shaft locations. The method of removal of such obstructions and the continuation of excavation shall be as proposed by the Contractor and approved by the Resident Engineer. The removal method for structures or obstructions may require special procedures and tools such as: chisels, bolder breakers, core barrels, down-the-hole hammers, air tools, hand excavation, temporary casing and increasing the hole diameter.

E. After providing Notice to Sound Transit and upon receiving direction from the Resident Engineer, the Contractor shall be required to continue with performance of all Work and maintain its progress to the extent possible with the work pending resolution of the unexpected removal of a structure or obstruction.

F. If the unexpected removal of a structure or obstruction results in idled or stopped drilled shaft excavation or support equipment, the standby cost for the first eight (8) work hours of idled equipment duration shall be considered incidental to the performance of the Contract. The cost of drilled shaft excavation or support equipment that is idled or stopped in excess of the cumulative eight (8) work hours and cannot be reasonably reassigned within the Project will be reimbursed as standby equipment as determined by the Resident Engineer.

G. Any drilling tools and other equipment that are lost in drilled shaft excavation shall not be considered structures or obstructions, and shall be promptly removed by the Contractor without compensation. All costs due to lost tool removal shall be borne by the Contractor including any remediation.

3.04 SLURRY (IF APPLICABLE)

A. Use slurry to maintain the stability of the drilled hole wall during excavation and concrete placement once water begins to enter the shaft and remain present at a depth of 6 inches or greater.
1. If casing is adequately sealed into competent soils such that water does not enter the excavation, Resident Engineer may allow excavation to continue in wet soils provided the water level within the casing does not rise or exhibit flow.

B. Synthetic Slurry Technical Assistance

1. Use synthetic slurries in conformance with the manufacturer's written directions.

2. If synthetic slurry is used, either a manufacturer's representative or a Contractor's employee trained in the use of the synthetic slurry, shall provide technical assistance for the use of the synthetic slurry, be at the site prior to introduction of the synthetic slurry into a drilled hole, and shall remain at the site during the construction and completion of a minimum of one (1) shaft to adjust the slurry mix to the specific site conditions.

3. After the manufacturer's representative is no longer present at the site, ensure Contractor's trained employee is present at the site throughout the remainder of the slurry operations to furnish technical assistance.

C. Minimum Level of Slurry in the Excavation

1. When slurry is used to stabilize the excavation, maintain the slurry level in the excavation above the groundwater level among the greatest of the following:
   
a. Ten feet for water slurries

   b. Ten feet for synthetic slurries, except when a lesser dimension is specifically recommended by the slurry manufacturer for the site conditions and construction method

   c. One shaft diameter

   d. As required to provide and maintain a stable excavation

2. Provide casing or other means as necessary to meet these requirements.

3. Maintain the slurry level above all unstable zones a sufficient distance to prevent bottom heave, caving, or sloughing.

4. Throughout all stops in shaft excavation operations, monitor and maintain the slurry level in the excavation the greater of the following elevations:
   
a. No lower than the water level elevation outside the shaft.

   b. Elevation as required to provide and maintain a stable hole.

D. Clean, recirculate, de-sand, or replace the slurry to maintain the required slurry properties.

E. Demonstrate to the satisfaction of the Resident Engineer that stable conditions are being maintained. If the Resident Engineer determines that stable conditions are not being maintained, immediately take action to stabilize the shaft. Submit a revised shaft installation plan that addresses the problem and prevents future instability. Do not continue with shaft construction until the damage that has already occurred is repaired in accordance with these Specifications, and until receiving the Resident Engineer's approval of the revised shaft installation plan.

F. Dispose of slurry and slurry-contacted spoils as specified in the CWP and in accordance with the following:
1. Water slurry with no additives may be infiltrated to uplands within the confines of the right-of-way for the project, provided that the ground surface at the disposal site is at least 5 feet above the current water table, and that disposal operations conform to the temporary erosion and sedimentation control (TESC) requirements established for the project. For the purposes of water slurry disposal, upland is defined as an area that has no chance of discharging directly to waters of the state, including wetlands or conveyances that indirectly head to wetlands or waters of the state.

2. Dispose of Synthetic slurry and water slurry with polymer-based additives at an approved facility. Acquire all permits or approvals necessary for disposal of the slurry prior to beginning shaft excavation operations. Provide copies of all permits or approvals to the Resident Engineer prior to beginning shaft excavation operations. Spoils in contact with synthetic slurry or water slurry with polymer based additives shall be contained and disposed of by the contract at an approved waste facility. Prior to beginning shaft excavation operations, coordinate with the waste facility operator and Jurisdictional Health Department (JHD) to determine requirements for shaft spoils disposal at the facility. Submit the location of the waste facility, requirements for disposal of shaft spoils (as approved by the waste facility operation and the JHD), copies of any permits required and obtain, and any associated test results to the Resident Engineer prior to disposal. Stockpile spoils on 6-mil plastic and cover with 6-mil plastic to protect from runoff until approval from the waste facility operator and JHD is given to dispose of the spoils.

3.05 PLACING REINFORCING

A. The reinforcing cage shall be rigidly braced to retain its configuration during handling and construction. Individual or loose bars will not be permitted.

B. Carefully position and securely fastened the reinforcing to provide the minimum clearances listed below, and to ensure that no displacement of the reinforcing steel bars occurs during placement of the concrete.

C. Place reinforcing steel spacers at least at the quarter points around the circumference of the steel reinforcing bar cage, and at a maximum longitudinal spacing of either 2.5 times the shaft diameter or 20 feet, whichever is less. Check the elevation of the top of the steel cage before and after placing the concrete. If the cage is not within the specified tolerances, correct, and do not construct additional shafts until receiving approval from the Engineer.

D. Place bars as shown in the Contract Documents with minimum concrete cover as noted:

1. Shaft diameter less than or equal to 3 feet: 3 inches
2. Shaft diameter greater than 3 feet and less than 5 feet: 4 inches
3. Shaft diameter greater than 5 feet: 6 inches

E. For shafts with temporary casing within 15 feet of the bottom of shaft elevation as noted on the Contract Drawings, Resident Engineer may allow use of quarry spalls or other rock backfill below the specified bottom of shaft elevation as a means to support the reinforcing cage.

3.06 INSTALLING ACCESS TUBES FOR CROSSHOLE SONIC LOGGING

A. Install access tubes for crosshole sonic log testing in all drilled shafts except those constructed completely in the dry excavation and shafts less than 3 feet in diameter.
B. Tubes may be extended with mechanical couplings. Duct tape or other wrapping material to seal the joints and butt welding of joints are prohibited. When couplings are used, record their location.

C. Securely attach the access tubes to the interior of the reinforcement cage of the shaft. Furnish and install one access tube for each foot of shaft diameter, rounded to the nearest whole number, but not less than 4, as shown in the Contract Documents. The access tubes shall be placed around the shaft, inside the spiral or hoop reinforcement, and bundled with the vertical reinforcement. Where circumferential components of the rebar cage bracing system prevent bundling the access tubes direction to the vertical reinforcement, the access tubes shall be placed inside the circumferential components of the rebar cage bracing system as close as possible to the nearest vertical reinforcement bar.

D. Install access tubes in straight alignment and as near to parallel to the vertical axis of the reinforcement cage as possible. Extend access tubes from the bottom of the reinforcement cage to at least 2 feet above either the top of the continuous concrete placement operation or the top of the shaft. Make all joints required to achieve full-length access tubes. Clear the access tubes of all debris and extraneous materials before installing the access tubes. Care shall be taken to prevent damaging the access tubes during reinforcement cage installation operations in the shaft excavation.

E. Fill the access tubes with potable water as soon as possible after concrete placement (but no later than 1 day), and reinstall the top watertight caps.

3.07 PLACING CONCRETE

A. Conform to Section 03 30 00, Cast-In-Place Concrete.

B. Place concrete immediately after completion of excavation by the Contractor and inspection by the Resident Engineer. Continue placing concrete in one operation to the top of the shaft, or as shown in the Contract Drawings. Place concrete between the upper construction joint of the shaft and the top of the shaft in the dry.

C. During concrete placement, monitor and minimize the difference in the level of concrete inside and outside the steel reinforcing cage. Conduct placement operations to maintain a maximum 1 foot differential.

D. When placing concrete in the dry, vibrate only the top 5 feet of concrete and the entire depth of the shaft-column reinforcing splice zone. If a temporary casing is used, remove it before vibration. This requirement may be waived if a temporary casing is used and removed with a vibratory hammer during the concrete placement operation. Vibration of the top 5 feet of concrete does not affect the maximum slump allowed for the concrete class specified.

E. If water is not present (less than 3 inches), deposit the concrete through the center of the reinforcement cage by a method that prevents segregation of aggregates and splashing of concrete on the reinforcement cage. Place the concrete such that the fall is vertical down the center of the shaft without hitting the sides of the drilled hole, the steel reinforcing bars, or the steel reinforcing bar cage bracing. Laborers with shovels are not generally able to direct the stream of concrete adequately. Do not allow free fall of concrete for more than 10 feet, use a concrete pump or tremie instead.

F. When placing concrete underwater, use a concrete pump or tremie. A tremie shall have a hopper at the top that empties into watertight tube at least 8 inches in diameter. If a pump is used, a watertight tube shall be used with a minimum diameter of 4 inches. The discharge end of the tube on the tremie or concrete pump shall include a device to seal out water while the tube is first filled with concrete.
G. Throughout the underwater concrete placement operation, keep the discharge end of the tube submerged in the concrete at least 5 feet and enough concrete in the tube to prevent water from entering. Place concrete continuously until the work is completed, resulting in a seamless, uniform shaft. If the concrete placement operation is interrupted, the Resident Engineer may require the Contractor to prove by core drilling or other tests that the shaft contains no voids or horizontal joints. If testing reveals voids or joints, repair them or replace the shaft.

H. Before placing fresh concrete against concrete deposited in water or slurry, remove all scum, laitance, loose gravel, and sediment on the upper surface of the concrete deposited in water or slurry and chip off high spots on the upper surface of the existing concrete that would prevent the steel reinforcing bar cage from being placed in the position required by the Contract Drawings.

I. Prior to performing any crosshole sonic logging, remove the concrete at the top of the shaft down to sound concrete.

3.08 PROTECTION

A. The Contractor’s construction operation in the vicinity of a drilled shaft excavation with freshly placed concrete and curing concrete should be in accordance with WSDOT Specifications 6-02.3(6)D, D1 and D2.

3.09 REMOVING CASING (IF APPLICABLE)

A. Maintain a minimum 5-foot head of concrete as the temporary casing is removed. Completely remove all temporary casings.

3.10 FIELD QUALITY CONTROL

A. Uniform Yield Form: Complete a uniform yield form for each shaft, consistent with the sample form submitted with the CWP.

B. Slurry Sampling and Testing

1. Mix and thoroughly hydrate synthetic slurry in slurry tanks, ponds, or storage areas.

2. Draw sample sets from the slurry storage facility and test the samples for conformance with the appropriate specified material properties before beginning slurry placement in the drilled hole. A sample set shall be composed of samples taken at mid-height and within 2 feet of the bottom of the storage area.

3. Sample and test all slurry in the presence of the Resident Engineer, unless otherwise directed. Record the date, time, names of the persons sampling and testing the slurry, and the results of the tests. Submit a copy of the recorded slurry test results to the Resident Engineer at the completion of each shaft, and during construction of each shaft when requested by the Resident Engineer.

4. When synthetic slurry is used, keep a written record of all additives and concentrations of the additives in the synthetic slurry. Transmit these records to the Resident Engineer once the slurry system has been established in the first drilled shaft on the project. Provide revised data to the Resident Engineer if changes are made to the type or concentration of additives during construction.

5. Take sample sets of all slurry, composed of samples taken at mid-height and within 2 feet of the bottom of the shaft, and test during drilling as necessary to verify the control of the properties of the slurry. Take and test sample sets of synthetic slurry at least once every four (4) hours after beginning its use during
each shift. Take and test sample sets of all slurry at least once every two (2) hours if the slurry is not recirculated in the drilled hole or if the previous sample set did not have consistent specified properties. Recirculate all slurry, or agitate with the drilling equipment, when tests show that the sample sets do not have consistent specified properties.

6. Take sample sets of all slurry and test prior to final cleaning of the bottom of the hole and again just prior to placing concrete. Do not start cleaning of the bottom of the hole and placement of the concrete until tests show that the samples taken have consistent specified properties.

C. Non-Destructive Testing of Drilled Shafts (Crosshole Sonic Logging)

1. Perform crosshole sonic log testing and analysis on all completed shafts greater than 3 feet. No need to perform testing if the shaft is constructed completely in dry hole.

2. Provide 48 hours of notice to the Resident Engineer prior to the time of crosshole sonic log testing.

3. Perform the testing after the shaft concrete has cured at least 96 hours.

4. After placing the shaft concrete and before beginning the crosshole sonic log testing of a shaft, inspect the access tubes. Replace each access tube that the test probe cannot pass through, at the Contractor’s expense, with a 2-inch diameter hole cored through the concrete for the entire length of the shaft. Unless directed otherwise by the Resident Engineer, locate cored holes approximately 6 inches inside the reinforcement and shall not damage the shaft reinforcement. Log descriptions of inclusions and voids in cored holes and submit a copy of the log to the Resident Engineer. Samples from cored holes shall be preserved, identified as to location, and made available for inspection by the Resident Engineer.

5. The Engineer of Record will determine final acceptance of each shaft, based on the crosshole sonic log test results and analysis for the tested shafts, and will provide a response to the Contractor within three (3) working days after receiving the test results and analysis submittal. Coring may be required to determine if the shafts are nonconforming when the CSLs results cannot provide the verification.

6. For shafts determined to be nonconforming, submit a plan for remedial action to the Resident Engineer for approval. All modifications to the dimensions of the shafts, as shown in the Plans, required by the remedial action plan shall be supported by calculations and working drawings. All remedial procedures and designs shall be submitted to the Resident Engineer for approval. Do not begin repair operations until receiving the Resident Engineer's approval of the remedial action plan. If the Contractor determines it is not feasible to repair the rejected pile, submit a mitigation plan for replacement or supplementation of the rejected pile.

7. If the Resident Engineer determines that the concrete placed under slurry for a given shaft is nonconforming, that shaft will be rejected. The placement of concrete under slurry shall be suspended until the Contractor submits to the Resident Engineer written changes to the methods of shaft construction needed to prevent future structurally inadequate shafts, and receives the Resident Engineer's written approval of the submittal.

D. Coring
1. At the Resident Engineer's request, drill a core hole in any questionable quality shaft (as determined from crosshole sonic log testing and analysis or by observation of the Resident Engineer) to explore the shaft condition. The Contractor shall submit to the Resident Engineer for approval of the proposed investigation method in any questionable quality shaft (as determined from crosshole sonic log testing and analysis or by observation of the Resident Engineer) to explore the shaft condition.

2. Prior to beginning coring, submit the method and equipment used to drill and remove cores from shaft concrete to the Resident Engineer and receives the Resident Engineer's written approval. The coring method and equipment shall provide for complete core recovery and shall minimize abrasion and erosion of the core. Coring shall not damage the shaft reinforcement.

3. Coring logs shall include core recovery, rock quality designation, locations of breaks, and complete descriptions of inclusions and voids encountered during coring.

E. Dewater all access tubes and cored holes and fill with grout after tests are completed. Use grout tubes that extend to the bottom of the access tube or hole or into the grout already placed.

F. Any costs including the schedule delay resulting from nonconforming drilled shafts shall be borne by the Contractor.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies furnishing, spreading, and compacting aggregate for base course.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)

1.03 SUBMITTALS
A. Materials sources, tests, and certifications.
B. Plans and field test reports shall be submitted in accordance with Articles 2.02 and 3.04 herein.

PART 2 - PRODUCTS

2.01 MATERIALS, EQUIPMENT, AND FACILITIES
A. Mineral aggregate type shall be furnished as indicated on Contract Drawings. Grading and quality shall conform to WSDOT Standard Specifications, Section 9-03.

2.02 SOURCE QUALITY CONTROL
A. Aggregates sources shall be selected and provided from WSDOT’s Aggregates Sources Approval data base. If aggregates are not from an approved source, the Contractor shall provide qualifying test data to certify the material is in compliance with specifications prior to its use.
B. Sampling and testing of aggregate base material shall be performed in accordance with WSDOT Standard Specifications, Section 3-04.

PART 3 - EXECUTION

3.01 EXAMINATION
A. Inspect subgrade with the Resident Engineer and obtain a written acceptance of the prepared subgrade, prior to the placement of aggregate base course.

3.02 PREPARATION
A. Perform subgrade preparation as indicated on the Contract Drawings and in accordance with Section 31 20 00, Earth Moving.
3.03 CONSTRUCTION

A. Place and compact aggregate base courses as indicated on the Contract Drawings and in accordance with WSDOT Standard Specifications, Section 4-04.

3.04 FIELD QUALITY CONTROL

A. Test for compliance of compaction and moisture control of aggregate base in accordance with WSDOT Standard Specifications, Section 2-03. When a material source changes, test each material independently.

B. Tolerances for maximum allowable deviation in surfacing thickness of Aggregate Base Course shall be 1/2 inch less than specified depth.

C. Sampling frequency for density and compaction of aggregate materials shall be as follows:

   - Embankment : 1-2500 CY
   - Cut Section : 1-500 LF
   - Surfacing and Subballast : 1-1000 LF
   - Backfill : 1-500 CY

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies furnishing and placement of Hot Mix Asphalt (HMA) on a prepared base, for roadways, sidewalks, and surface parking facilities.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:
   1. Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)
   2. Standard plans and specifications of Agency Having Jurisdiction (AHJ)

B. Definitions
   1. Hot Mix Asphalt (HMA): A plant-mixed asphalt concrete pavement composed of asphalt binder and mineral aggregate as specified, mixed in specified proportions at a predetermined temperature to provide a homogenous, stable, workable, and compactable mixture.

1.03 SUBMITTALS

A. Mix design, as specified in WSDOT Standard Specifications, Section 5-04, and test result such as material sources, gradation, classification, and plant certification.

B. Paving plan for areas under traffic, as specified in WSDOT Standard Specifications, Section 5-04.

C. Inspection reports shall be submitted to the Resident Engineer, within 24 hours of HMA placement.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Maximum nominal aggregate size shall be as shown on the Contract Drawings. Aggregates for HMA shall conform to WSDOT Standard Specifications, Section 9-03.8.

B. Asphalt binder grade shall be as shown on the Contract Drawings, in accordance with WSDOT Standard Specifications, Section 9-02.1(4). The Contractor may propose alternate grades.

C. Tack coat shall be CSS-1 or CSS-1h emulsified asphalt, in accordance with WSDOT Standard Specifications, Section 9-02.1(6).

D. Anti-stripping additive shall conform to WSDOT Standard Specifications, Section 9-02.4.
E. Existing HMA mix designs that are continuously approved by WSDOT or AHJ may be proposed for acceptance, as long as the designs fulfill performance requirements specified in WSDOT Standard Specifications, Section 5-04.

2.02 SOURCE QUALITY CONTROL

A. Aggregates proposed to be used for HMA shall be tested, in accordance with WSDOT Standard Specifications, Section 5-04 and Section 9-03.8.

B. Acceptance sampling and testing of HMA shall be performed, in accordance with WSDOT Standard Specifications, Section 5-04.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prepare subgrade and construct aggregate base course as indicated on the Contract Drawings, and in accordance with Section 32 11 23, Aggregate Base Courses.

B. Surface Preparation of Existing Pavements:
   1. When an existing paved surface will be used as a base for one or more courses of HMA, begin by cleaning the entire existing pavement surface.
   2. Remove all fatty asphalt patches, grease drippings and other objectionable matter from the existing pavement. Sweep existing pavement with a power broom until clean of dust, soil, pavement grindings, and other foreign matter. Fill all holes and small depressions with HMA. Level and compact any patched areas.
   3. Apply tack coat to all paved surfaces on which any course of HMA shall be placed or abutted, in accordance with WSDOT Standard Specifications Section 5-04.

3.02 CONSTRUCTION

A. Provide, place, and compact asphalt pavement true to line, joint, grade, thickness, and typical cross-section indicated on the Contract Drawings, and in accordance with WSDOT Standard Specifications, Section 5-04.

B. For asphalt pavement patching within the City right-of-way, construction shall also comply with AHJ pavement restoration requirements.

3.03 FIELD QUALITY CONTROL

A. Perform compaction test and surface smoothness test for asphalt pavement, as in accordance with WSDOT Standard Specification, Section 5-04. Asphalt thickness shall be included in compaction report.

B. Allow newly constructed asphalt pavement to cool to ambient temperature, before opening pavement to traffic.

C. Verify WSDOT Standard Specification, Section 5-04.3(13) Surface Smoothness has been met, apply fog seal to pavement surface, and obtain approval from the Resident Engineer, before opening pavement to traffic.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies furnishing and placement of Portland cement concrete pavement for roadways, sidewalks, and curb ramps.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:

1. American Society for Testing and Materials International (ASTM)
   a. ASTM A615/A615M Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
   b. ASTM C143/C143M Standard Test Method for Slump of Hydraulic Cement Concrete

2. Standard Plans and Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)

3. Standard plans and specifications of Authority Having Jurisdiction (AHJ)

4. Public Right of Way Accessibility Guidelines (PROWAG)

5. ADA Accessibility Guideline (ADAAG)

1.03 SUBMITTALS

A. Product data, such as concrete admixtures, curing compounds, joint filler, and detectable warning surface.

B. Concrete mix design as specified in WSDOT Standard Specifications, Section 5-05. Submittal shall include the following:

1. Manufacturer’s Certificate of Compliance

2. Sources, batch weights, and gradation reports of coarse and fine aggregates

3. Mix proportions per cubic yards, which includes water cement ratio, aggregate proportions, fineness modulus, and entrained air volume

4. Average 28-day compressive strength

C. Shop drawings, including the following:

   1. Concrete type and class
2. Concrete placement method, sequence, locations, boundaries, and quantity in cubic yards

3. Construction joints, expansion and contraction joints, and isolation joints locations

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials for construction of concrete pavement shall include Portland cement, aggregates, reinforcing steel, curing compounds, and admixtures, as specified in WSDOT Standard Specifications, Section 5-05. High-early-strength Portland cement concrete mixes may be used with approval of the Resident Engineer.

B. Maximum nominal size of aggregate is defined as the smallest standard sieve opening, through which the aggregate unit is permitted to pass.

C. The contractor is responsible for concrete placeability, workability, and strength.

D. Detectable warning surface shall conform to WSDOT Standard Specification Section 8-14.2.

2.02 SOURCE QUALITY CONTROL

A. Materials proposed to be used for construction shall be verified and tested, in accordance with WSDOT Standard Specification, Section 5-05 and Division 9.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prepare subgrade in accordance with Section 31 20 00, Earth Moving.

B. Construct aggregate base course as indicated on the Contract Drawings, and in accordance with Section 32 11 23, Aggregate Base Courses.

3.02 CONSTRUCTION

A. Construct concrete pavement true to line, grade, thickness, and typical cross-section indicated on the Contract Drawings, in accordance with WSDOT Standard Specifications Section 5-05 and AHJ requirements. Remove and replace pavement that is not within tolerances for line, grade, thickness and cross-section.

B. Construct concrete driveways, as indicated on the Contract Drawings, in accordance with WSDOT Standard Specifications Section 8-06 and AHJ requirements.

C. Construct concrete sidewalks and curb ramps, as indicated on the Contract Drawings, in accordance with WSDOT Standard Specifications, Section 8-14, WSDOT Standard Plans and AHJ requirements.

D. Construct concrete patching for roadways, in accordance with WSDOT Standard Specifications, Section 5-05.3 and AHJ requirements. For pavement and sidewalks concrete patching within the City right-of-way, construction shall also comply with AHJ pavement restoration requirements.
3.03 FIELD QUALITY CONTROL

A. Perform acceptance testing of concrete pavement, in accordance with WSDOT Standard Specification, Section 5-05 and AHJ requirements.

B. Verify WSDOT Standard Specification, Section 5-05.3(17) has been met, and obtain approval from the Resident Engineer, before opening newly constructed pavement to traffic.

END OF SECTION
SECTION 32 16 13
CONCRETE CURBS AND GUTTERS

PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies furnishing and installation of concrete curbs and gutters.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. American Society for Testing and Materials International (ASTM)
      a. ASTM A615/A615M Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
      b. ASTM C143/C143M Standard Test Method for Slump of Hydraulic Cement Concrete
   2. Standard Plans and Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)
   3. Standard plans and specifications of Authority Having Jurisdiction (AHJ)
   4. Public Right of Way Accessibility Guidelines (PROWAG)
   5. ADA Accessibility Guideline (ADAAG)

1.03 SUBMITTALS
A. Product data for all materials.
B. Concrete mix design and test results in accordance with WSDOT Standard Specifications Section 6-02.3(2)A & B.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Concrete for extruded concrete curbs shall have minimum compressive strength at 28-day of 3000 pounds per square inches. Slump shall not be greater than 1 inch in accordance with ASTM C143/C143M. Maximum coarse aggregate shall not be greater than 3/4 inch. Air entrainment shall be 5 percent plus or minus 1.5 percent.
B. Concrete for Cast-in-Place Curbs shall be Class 3000 in accordance with WSDOT Standard Specifications Section 6-02.3(2).
C. Portland cement shall conform to Section 03 05 15, Portland Cement Concrete.

D. Dowels and reinforcing steel shall be No. 3 deformed steel billet bars, in accordance with ASTM A615/A615M, Grade 60.

E. Curing compound shall be Type 1D, Class B, in accordance with WSDOT Standard Specifications, Section 9-23.2.

F. Pre-molded joint filler shall conform to WSDOT Standard Specifications, Section 9-04.1.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. General

1. Construct curbs or curbs and gutters in accordance with WSDOT Standard Specifications, Section 8-04 or AHJ requirements.

2. Construct curbs or curbs and gutters as indicated on the Contract Drawings, and as referenced in WSDOT Standard Plan F-10.12 or in accordance with AHJ Standard Plans.

B. Extruded Concrete Curbs

1. Place, compact, and shape extruded concrete curb true to line and grade, with a curb machine approved by Resident Engineer. Use a curb machine capable of shaping and compacting concrete to the required cross section.

2. Dry and rid pavement of loose and deleterious materials prior to curb placement. Anchor curbs to existing pavement using epoxy bonding agent, in accordance with manufacturer recommendations.

3. Load curb machine hopper with homogenous cement mix. Run each load of cement mix through the curb machine; adjust machine to form and compact cement mix to the required cross section.

4. Space joints in curb at 15-foot intervals, or space joints to match existing transverse joints or cracks in existing pavement. Cut joints vertically.

5. Use Type 1D, Class B curing compound with pigment, to make sprayed compound easily discernible.

6. Protect newly placed curb from traffic by barricades or other suitable means, until curb has attained its required strength of 2500 pounds per square inch. Keep protection in place for at least 72 hours.

C. Cast-in-Place Curbs or Curbs and Gutters

1. Construct curbs or curbs and Gutters in accordance with WSDOT Standard Specifications, Section 8-04.3 and AHJ requirements.

3.02 FIELD QUALITY CONTROL

A. Verify that grade does not deviate more than 1/8 inch and alignment does not vary more than 1/4 inch, when checking with a 10-foot straightedge.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for furnishing and installing pavement marking.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
1. Washington State Department of Transportation (WSDOT)
   a. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
   b. WSDOT Standard Plans
   c. Manual on Uniform Traffic Control Devices (MUTCD) – WSDOT Modifications
2. Federal Highway Administration (FHWA)
   a. Manual on Uniform Traffic Control Devices (MUTCD)
3. Standards per local AHJ.

1.03 SUBMITTALS
A. Product Data: the respective manufacturers’ product data for pavement marking materials.

PART 2 - PRODUCTS

2.01 MATERIALS - GENERAL
A. For pavement markings on Sound Transit owned streets, roadways, and parking lots, the materials used in the Work shall be as indicated on the Contract Drawings and conform to WSDOT Standard Specifications Sections 8-09 and 8-22, unless specified otherwise.

B. For pavement markings on streets, roadways, and parking areas that will be owned or maintained by local jurisdictions, use materials that conform to their Design Manual Standard Drawings, and conform to applicable provisions of WSDOT Standard Specifications Sections 8-07, 8-09 and 8-22, unless specified otherwise.

2.02 CONSTRUCTION - GENERAL
A. For pavement markings on Sound Transit owned streets, roadways, and parking lots, the work described in this Section shall be performed in accordance with WSDOT Standard Specifications Sections 8-09 and 8-22 unless specified otherwise.
B. For pavement markings on streets, roadways and parking areas that will be owned or maintained by local jurisdictions, perform work described in this Section in accordance with their Design Manual Standard Drawings, and applicable provisions of WSDOT Standard Specifications Sections 8-09 and 8-22, unless specified otherwise.

C. Removal of pavement markings shall be performed in accordance with WSDOT Standard Specifications Sections 8-22 and 8-23.

D. For existing asphalt pavement areas in parking lots that will have pavement marking(s) installed by this contract, place a bituminous seal coat over the existing pavement prior to placing proposed pavement marking(s). Placement of the bituminous seal coat shall be in accordance with WSDOT Standard Specifications Section 5-02.1(3).

2.03 TEMPORARY PAVEMENT MARKINGS

A. For temporary pavement markings on WSDOT facilities reference requirements in WSDOT Standard Specifications Sections 8-23 and the contract plans.

B. For temporary pavement markings on facilities with local jurisdictions or Sound Transit, reference contract plans and requirements of the AHJ

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies furnishing and installation of permanent security fencing, which includes gates, posts, links, wires, fittings, hardware, anchors, and concrete footings.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents:

1. American Society for Testing and Materials International (ASTM)
   a. ASTM A121 Standard Specification for Metallic-Coated Carbon Steel Barbed Wire
   b. ASTM A153/A153M Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   c. ASTM F567 Standard Practice for Installation of Chain-Link Fence
   d. ASTM F626 Standard Specification for Fence Fittings

2. American Association of Station Highway and Transportation Officials (AASHTO)
   a. AASHTO M 181 Standard Specification for Chain-Link Fence
   b. AASHTO T 22 Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens
   c. AASHTO T 152 Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method

3. Standard Specifications for Road, Bridge, and Municipal Construction (WSDOT)

4. Standard plans and specifications of Authority Having Jurisdiction (AHJ)

1.03 SUBMITTALS

A. Product data for all materials to be incorporated into fencing and gates.

B. Shop drawings of fencing including gates layout and installation details.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Fencing shall include framework, concrete footings, fabric covering, hardware, and other accessories as required, for a complete installation.
B. Posts and rails shall conform to WSDOT Standard Specifications, Section 9-16.1. Posts and rails shall be black vinyl coated.

C. Tension wires shall conform to AASHTO M 181, Class 1. Wires shall be galvanized and colored black.

D. Concrete footing shall have minimum compressive strength at 28-days of 3000 pound per square inches, in accordance with AASHTO T 22. Concrete shall have air content between 4.5 percent and 7.5 percent, in accordance with AASHTO T 152.

E. Chain link gate frames shall be constructed with no less than 1-1/2 inches inside diameter steel pipes, hot-dip galvanized, with nominal weight of 2.72 pounds per linear foot. Each gate shall be completed with hinges, latch, and drop bar locking device suitable for fencing system. The latch device shall have provision for padlocking. All components shall be colored black.

1. Corners of the gate frame shall be fastened together and reinforced with a malleable iron or pressed steel fitting designed for that purpose, or corners shall be welded together.

2. Welding shall conform to WSDOT Specification Section, 6-03.3(25). Welds shall be grinded smooth and painted with a high zinc dust content paint, meeting the requirements of MIL-P-21035B. Paint shall be applied in coats to achieve a dry film thickness of 3.5 millimeters minimum.

3. Cross trussing shall be made of 3/8 inch galvanized, adjustable steel rods.

4. If gate frames are to be constructed with materials other than steel pipes, the construction of gate shall have equal or better rigidity; approval from the Resident Engineer shall be obtained.

F. Chain link fencing fabric shall be 9 gage, zinc-coated steel wire woven into approximately 2-inch diamond mesh, conforming to AASHTO M 181, Class C. Fabric shall be black vinyl clad.

G. Fittings and hardware shall be made of malleable cast iron or pressed steel, conforming to ASTM F626. Any galvanizing of hardware not covered by ASTM F626 shall conform to ASTM A153/A153M. Fittings for fence shall be furnished by the fence manufacturer.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Stake locations of fence lines, terminal posts, and underground utilities. Clear and grade both sides of the fence line as required.

B. Install posts at equal distances, not greater than 10 feet, unless noted otherwise. Set posts at correct heights and spacing; hold posts in place during concrete setting.

C. Place concrete fill around posts to the dimensions indicated; vibrate or tamper concrete fill for consolidation. Crown top of footings to shed water. Protect posts above ground from concrete splatter.

D. Install fencing and gates in accordance with ASTM F567.

E. Install drop bar inserts in both open and closed positions of gates, so that gates can be secured in either position.
3.02 REMOVE AND RESET FENCE

A. Any existing fence that is removed to facilitate construction, but not indicated on Contract Drawing for removal, shall be protected, stored, and reinstalled to its original location and condition upon completion of the work.

B. Remove and dispose of any existing fence and gates that are damaged during construction operations; replace all damaged sections with new fence and gates of equal or better materials, and construct in accordance with Contract documents and AHJ requirement.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies the maintenance, support, and protection of existing utilities as indicated.

1.02 SUBMITTALS
A. Schedule of estimated utility shut-downs for each utility affected. Include the date of shut-down and duration.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL
A. Existing utilities shall be field-located in accordance with RCW 19.122 by contacting Call Before You Dig at 1-800-424-5555. Field-located utilities shall be checked against the composite utility plans.
B. Maintain existing utilities and protect from damage in accordance with the requirements of the utility owner and applicable codes and regulations.
C. Existing utilities and services shall not be operated, disconnected, or shut down except by permission of Sound Transit, Utility owners, and (if applicable), the authorities having jurisdiction. Submit a schedule of estimated shut-down time, and notify all interested parties, neighbors, utilities, and municipal and county authorities, as required.
D. Utilities to be removed shall not be removed until shut-down time can be kept to the minimum length of time possible. Do not remove any existing utility line or service until the replacement line, crossover, or capping is ready to be performed.
E. When existing utility services occupy the same trench space as a new utility, the excavation shall completely expose such existing services. Exposed existing utilities shall be protected.
F. In the event of conflict with other underground utilities, immediately notify the Resident Engineer.
G. Protect existing utilities from damage. Shoring, underpinning and structural support shall be provided for existing utility lines and structures as required to protect and support the utility from damage, movement, and subsidence as may be incurred because of adjacent excavation operations.
H. Unforeseen existing utilities shall be recorded on the as-built drawings.
I. Provide temporary utility services as required or as specified.
3.02 REQUIRED NOTIFICATIONS

A. Underground utilities shall be field-located and marked for identification by the affected utility companies before performing any excavation or other work close to any underground pipeline, conduit, duct, wire, or other structure. The Contractor shall notify the Resident Engineer and the utility owners a minimum of 2 and a maximum of 10 business days before performing any such excavation work. Notify affected utilities before digging by calling Call Before You Dig at 1-800-424-5555. For utility owners not covered by this telephone number, such as owners of gravity sewer and storm drainage facilities, contact the affected utility owners directly.

B. If underground utilities are damaged in any way, notify the Resident Engineer and affected utilities immediately for corrective action.

3.03 RELOCATION OF EXISTING UTILITIES BY OTHERS

A. Certain utilities will be relocated by the affected utility companies.

END OF SECTION
SECTION 34 05 17
TRACK CONSTRUCTION

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes requirements for general information concerning rail transit track construction as indicated on the Contract Documents, and as specified herein.

   1. Types of track construction are as follows:
      a. Ballasted track
      b. Direct fixation track
      c. Embedded track

B. Track construction includes all pertinent trackwork, special trackwork, and related items such as rail welds, insulated joints, rail cutting and stress adjustment, tamping, surfacing, lining and gauging and other operations necessary to construct an acceptable and completed track structure.

1.02 DEFINITIONS

A. The use of the following terms in these Specifications and the Contract Documents shall be interpreted as specified herein:

   1. Anchor Insert – Component of direct fixation track which is embedded into concrete support, typical metal with threads, to receive anchor bolt.

   2. Anchor Plate - A device used in embedded track to secure running rails to concrete slab at the proper track gauge to provide vertical, lateral and longitudinal restraint of the rail.

   3. At-Grade Road Crossing - The crossing of a railway track and a vehicular roadway at the same elevation.

   4. At-Grade Track Crossing - The crossing of two or more railway tracks at the same elevation. See Crossing, Diamond.

   5. Ballast – An integral part of the track structure, generally composed of graded mineral aggregate, in which ties are implanted.

   6. Ballast Mat – Consists of natural rubber with fabric reinforcement designed to minimize ground borne vibration and provide a reduction in the impact on structures or structure-borne vibrations. Ballast mat also reduces the impact load on ballast.

   7. Bumping Post - A steel frame device placed at the end of tracks to prevent a moving rail vehicle from rolling off the end of track.

   8. Closure Rails - The rails placed between components of special trackwork units, such as the rails between the switch and the frog in a turnout.
9. Continuous Welded Rail (CWR) - A number of rails welded together into a continuous string.

10. Crossing or Crossing Diamond - An assembly of four frogs, connecting rails and guard rails that allow an at-grade railway crossing where two tracks cross or intersect each other requiring special trackwork.

11. Crossover, Single – Two turnouts, with track located between the frogs and arranged to form a continuous passage between two adjacent and generally parallel tracks.

12. Crossover, Double – Two single crossovers that intersect between two adjacent and generally parallel tracks forming connections between each track in each direction.

13. Crossover, Universal – Two single crossovers, which in close proximity and opposite hand between two adjacent and generally parallel tracks forming connections between each track in each direction.

14. Dutchman – A temporary rail segment inserted between two rail strings during the laying of CWR.

15. Fastenings - A general term applied to a device used to restrain the rail in place and include such parts as shims, fastener body, anchor bolts, inserts, spring clips, insulators, etc.

16. Fastener, Direct Fixation – A bonded plate-type assembly to hold the rail in place on a concrete support, where elastomer is vulcanized (bonded) to the top steel plate and, in most designs, to a bottom steel plate. Fasteners are either standard or high resilient depending on the stiffness.

17. Frog - A track device used at the intersection of two running rails to provide support for wheel treads and passageways for wheel flanges, thus permitting wheels traversing either rail to cross the other rail.

18. Frog Number - The number used to designate the size of a frog, and being equal to one-half the cotangent of one-half the frog angle or the number of units of centerline length when the spread N is one unit.

19. Gauge or Track Gauge - The distance between the inside faces of running rails of a track, measured at a point 5/8-inch below the top of rail. The standard gauge distance shall be 4-feet 8-1/2-inches.

20. Guard Rail, Main Track - A parallel rail installed inside of the running rail to support a wheel set if it comes off the track. See Guard Rail, Special Trackwork and Restraining Rail.

21. Guard Rail, Special Trackwork - A parallel rail or support installed inside of special trackwork to hold wheels on the correct alignment and preventing the wheel flanges from striking the points of turnout or frog.

22. Inside Rail - On curved track, the rail nearest to the curve center; the rail with the shorter radius. Also referred to as the "low rail".

23. Joint Bar – Device used to join the abutting ends of two rails of the same cross section.

24. Joint Bar, Compromise - A joint bar used to connect two rails of different cross sections.
25. Joint Bar, Insulated - Joint bar used to arrest the flow of electric current between two rails. Standard types are bonded and non-bonded.

26. Outside Rails - On curved track, the rail farthest from the curve center; the rail with the longer radius. Also referred to as the "high rail".

27. Pedestrian Crossing - The crossing of a railway track and a pedestrian sidewalk at the same elevation.

28. Premium or High Strength Rail - Rail having greater hardness than standard rail for use at locations of high rail wear. Premium or High Strength Rail shall be head hardened.

29. Profile Grade Line (PGL) - The datum line that defines the vertical alignment of the track, applied at the centerline of track at the top of the rail elevation on tangent track and the top of the inside (low) rail elevation on curves.

30. Rail Anchor – A device that clamps to the base of a rail and bears against the side of a cross tie to restrain longitudinal movement of the rail.

31. Rail, Tee - Common class of steel rail design symmetrical in section and resembles an inverted letter "T."

32. Restraining Rail - A fabricated rail installed parallel on the inside of the running rail (or both running rails) of small radius curved track to reduce wear on the running.

33. Running Rails - Support rails of a track on which the vehicle wheel tread contact and travel.

34. Screw Spikes - A threaded fastener for ballasted track construction that secures tie plates and special trackwork plates to timber crossties and switch ties.

35. Special Trackwork - A generic term referring to turnouts, single and double crossovers, crossings, and other items.

36. Stock Rail - A running rail that a switch point rail mates against in a turnout.

37. Subballast - A material superior in composition to the subgrade material that provides a semi-impervious layer between the track ballast and the subgrade to provide better drainage and distribution of loads to the subgrade.

38. Subgrade - The finished embankment or excavation below the level of subballast.

39. Superelevation - In curved track, the amount that the outside rail is raised above the inside rail. The inside rail elevation is maintained at the PGL top of rail profile.

40. Switch or Point of Switch - The tip of the tapered end of a switch point rail; the end of a switch rail farthest from the frog.

41. Switch Point, Switch Rail - The fabricated movable point rail of a turnout.

42. Switch, Undercut - A switch in which the stock rails are undercut to mate with or nest the switch rails so that the actual point of the switch rail head does not protrude beyond the original outline of the stock rail's head outline, commonly called a Samson switch point.

43. Tie or Cross Tie - Portion of track structure placed in ballast perpendicular to rail to hold track gauge and rail alignment.
44. Top of Rail (T/R) - That portion of the running rail that follows the PGL. Top of rail elevation is measured at the centerline of the rail.

45. Track, Ballasted - Track constructed of ballast, crossties, tie plates, rails and fastenings.

46. Track, Direct Fixation - Track constructed of concrete slab or plinth, rails and fastenings. Rails are connected to the concrete with fasteners, anchor bolts and anchors.

47. Track, Embedded - Track intended for joint usage with roadway vehicle traffic, with rails electrically isolated and at the same elevation as roadway surface.

48. Track Foot - Unit of measurement for all types of track construction; measured along the centerline of track.

49. Track, Main Line - Revenue service tracks designated by route name and direction.

50. Track, Shop - Track constructed within the Maintenance Facility building or perimeter aprons, generally direct fixation track, embedded track or open track supported across vehicle service pits.

51. Track, Storage - Are non-revenue tracks, the function of these tracks are low volume storage and/or light maintenance.

52. Track, Yard - Tracks within a yard for the purpose of switching, storing, or maintaining numerous light rail vehicles.

53. Track Slab - The reinforced concrete foundation that supports the track, generally in conjunction with embedded track, shop track, and at-grade direct fixation track.

54. Transition Slab - A reinforced concrete slab located at the junction of ballasted track and direct fixation track or embedded track to provide a transition between ballasted track construction and other types of track that have significantly different track modulus.

55. Turnout - A track arrangement consisting of a switch, frog, stock rails, closure rails, and guard rails enabling rail vehicles to be diverted from one track to another.

56. Turnout Number - The number corresponding to the number of the frog used in a turnout.

1.03 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   b. Portfolio of Trackwork Plans (AREMA Plans)

2. American Association of State Highway and Transportation Officials (AASHTO):
   a. AASHTO Standard Specifications for Highway Bridges
   b. AASHTO T 277 Standard Method of Test for Electrical Indication of Concrete’s Ability to Resist Chloride Ion Penetration
3. ASTM International (ASTM)
   a. ASTM A36/A36M Standard Specification for Carbon Structural Steel
   b. ASTM A153/A153M Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   c. ASTM A307 Standard Specification for Carbon Steel Bolts, Studs, And Threaded Rod 60,000 psi Tensile Strength
   d. ASTM F3125/F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions
   e. ASTM A563 Standard Specification for Carbon and Alloy Steel Nuts
   f. ASTM C203 Standard Test Methods for Breaking Load and Flexural Properties of Block-Type Thermal Insulation
   g. ASTM C307 Standard Test Method for Tensile Strength of Chemical-Resistant Mortar, Grouts, and Monolithic Surfacings
   h. ASTM C579 Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes
   i. ASTM C827 Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures
   j. ASTM D149 Standard Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
   k. ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials
   l. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
   m. ASTM D471 Standard Test Method for Rubber Property – Effects of Liquids
   n. ASTM D570 Standard Test Method for Water Absorption of Plastics
   o. ASTM D638 Standard Test Method for Tensile Properties of Plastics
   p. ASTM D6938 Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)
   q. ASTM D790 Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
   r. ASTM D2240 Standard Test Method for Rubber Property – Durometer Hardness
   s. ASTM E10 Standard Test Method for Brinell Hardness of Metallic Materials

4. American Concrete Institute (ACI)
a. ACI 503.1-503.4 Four Epoxy Standards

5. Washington State Department of Transportation (WSDOT):
   a. WSDOT M 41-10 Standard Specifications for Road, Bridges, and Municipal Construction
   b. WSDOT M 46-01 Materials Manual

1.04 SUBMITTALS

A. Qualification Documents and Statements: Transmit documentation pertaining to conformance of the requirements as specified herein. Document shall include Supplier’s certification that furnished products meet requirements as specified herein.

B. Technical Data:
   1. Submit Technical Data including shop drawings and specifications, for all special trackwork, showing the geometry, layout and materials list.
   2. Submit Technical Data including shop drawings and specifications, for high resilient direct fixation fasteners, showing geometry, layout and materials list.

C. Work Plan: Submit Work Plan for all track construction organized by track construction type, and in accordance with the Contract Documents.
   1. Submit the Work Plan prior to the commencing mock-up (demonstration section) construction activities.
   3. Work Plan shall include the following information or by reference, at a minimum:
      a. Proposed alignment survey control plan, including personnel, approach, and equipment.
         1) Submit actual alignment survey control and construction coordinate network (points, northing, easting, and elevation).
      b. List of construction tools and equipment to be used during the track construction, include construction equipment data (i.e. - height, width, length, weight) and loading diagrams. The equipment shall be subject to inspection by the Resident Engineer during use on the project.
      c. Step by step construction sequence.
      d. Material handling procedure, including tie, subballast, ballast, CWR, and special trackwork.
      e. Special equipment and tools.
      f. Documents of forms and jigs to support the track construction including ties, fasteners, and anchor inserts.
      g. Concrete placement approach to forming, placing, finishing, and curing of track concrete, including drilling, grouting and reinforcement installation.
h. Installation rail fastener with anchors inserts, including the anchor bolt installation torque and the sequence of shimming and applying spring clips in accordance with the Supplier's instructions.

i. CWR Adjusting, Field Welding, and Anchoring: Zero thermal force requirements.

j. Field Testing and Inspecting: Quality requirements and tolerances as specified herein.

k. Repair procedures for damaged rail, concrete, fasteners, inserts and non-conforming track alignment. Procedure shall cover at least the following items:
   1) Removal methods.
   2) Replacement materials including source, shelf life, and current cost.
   3) Bonding methods.
   4) Welding methods.
   5) Installation methods.

l. Rail end-hardening procedure and testing, including a list of qualified personnel who will perform the end-hardening and testing in the field.

m. Method for developing, documenting, and transmitting, CWR laying records.

n. Documents showing the proposed method for clamping the rail for embedded track during installation of concrete track base slab (1st pour) and/or elastomeric grout of embedded track.

o. Rail grinding equipment, method of operation.

p. Proposed staging areas for rail.

q. Method of transporting rail.

r. Haul routes and approved traffic control plans as required.

s. Required rail temperature record forms for rail laying and rail fastening operations.

D. Corrective Method Action Plan: Submit a plan including the following.

   1. Computer generated spreadsheets indicating the precise as-built concrete slab conditions, indicate the out-of-tolerance concrete installations.

   2. Computer generated spreadsheets indicating the established construction profile grade line to suit the existing as-built concrete base slab surface conditions.

   3. Detailed narrative outlining the specified corrective methods to be used to correct the concrete slab. The narrative shall clearly describe the limits of the correction by station, the type of correction (removal or grinding), and the magnitude (height) of each correction for each rail.
E. Transmit electrical resistance test results.
   1. Electrical resistance test results.

F. Provide to Sound Transit, six (6) rail thermometers, equal to those being used by the Contractor to measure rail temperature.

G. Submit final alignment survey of track geometry as specified herein.

1.05 MOCK-UP (DEMONSTRATION SECTION)

A. To validate the Work Plan and demonstrate the Contractor’s ability to deliver each track construction type by constructing a demonstration section a minimum of 30 days prior to the scheduled beginning of main line track construction.
   1. Utilize the exact procedure as specified in the Work Plan. Construct the demonstration section to the length of at least one complete production or construction cycle but not less than 150-feet. If the demonstration section does not meet the requirements as specified in the Contract Documents, submit a revised Work Plan and construct another demonstration section or sections as required.

PART 2 - PRODUCTS

2.01 MATERIALS

A. All track construction materials shall be new, except as specified herein.

B. Furnish all track construction materials and incidental materials required for complete construction of track.

2.02 INSPECTION OF MATERIALS

A. Furnished materials and products shall be presented for inspection at the place of manufacture.

B. Afford the Resident Engineer access without charge, to necessary facilities to examine the Work, at any time during this process, as well as the finished product, to ensure that the materials and products comply with the Contract Documents. Examination of the products is expected to take place during normal working hours.

C. Materials and products for inspection shall be presented in a safe area away from excessive noise and manufacturing activities.

D. Present to the Resident Engineer written notice for need of inspection a minimum of 30 days in advance, for scheduling purposes of the inspection. Contractor shall be responsible for additional travel costs associated with any cancellation or rescheduling of inspections initiated by the Contractor.

PART 3 - EXECUTION

3.01 GENERAL

A. Construct track in accordance with the Work Plan, demonstration section and applicable requirements, as specified herein and as indicated on the Contract Documents.
3.02 CONSTRUCTION EQUIPMENT

A. Track gauge, guard rail, flangeway width, curve radii, rail sections, and special trackwork components are designed for Sound Transit Light Rail Vehicle operation. Modify on-track construction equipment, as required, to operate over this track without causing damage to the rail, fasteners, track structure or trackwork. Damages shall be repaired by the Contractor at no additional cost to Sound Transit.

B. Clearance for the on-track equipment shall conform to the requirements for vehicle clearances, as specified in Sound Transit Design Criteria Manual, Chapter 4, Track Alignment and Vehicle Clearance.

C. Contractor's equipment shall not exceed structural design requirements including loads and conditions, as specified in Sound Transit Design Criteria Manual, Chapter 8, Structural.

D. Further information concerning Sound Transit design criteria will be provided by Sound Transit upon request by the Contractor.

3.03 ALIGNMENT SURVEY CONTROL DATA

A. Alignment information shown on the Contract Documents refers to geometric control points for the track.

B. Engineering stationing is used to reference geometric control points. Independent stationing will be used for each track.

C. Mathematized centerline alignment data for each track is included on the Contract Documents.

3.04 TRACK GEOMETRY

A. Construct track to conform to the alignment and profile data as indicated on the Contract Documents and as specified herein.

B. For tangent track the alignment is based on each centerline of track, equidistant between the gauge sides of the running rails.

C. For curved track, the alignment is based on the centerline of track with the outside rail located 2-feet 4-1/4-inches radial from the centerline measured at the gauge line of the rails.

D. Track gauge:
   1. Track gauge shall be 4-feet and 8-1/2-inches, measured 5/8-inch below top of rail plane.
   2. Special trackwork track gauge shall be as indicated on the approved Technical Data.

E. Rail Cant (Inclination):
   1. Special trackwork shall have zero rail cant.
   2. Ballasted track shall have rail cant at 40 to 1 inward inclination of the rail.
   3. Direct fixation track shall have rail cant at 40 to 1 inward inclination of the rail.
   4. Embedded track shall have rail cant at 40 to 1 inward inclination of the rail.
F. Superelevation:

1. Track superelevation shall be accomplished by maintaining the inside or low rail of the curve at top of rail profile grade line elevation and rotating the outside or high rail to the raised position developing a superelevated top of rail plane equal to $E_a$, except for reverse curves. Superelevated or non-superelevated top of rail planes shall be always parallel to the bottom of rail plane. Reverse curve superelevation shall be accomplished as indicated on the Contract Drawings.

2. The superelevation at the tangent-to-spiral point shall be zero and shall increase uniformly through the length of the spiral to full elevation of the outer rail at the spiral-to-curve point, unless otherwise shown on the Contract Documents. Provide spiral and superelevation at the ends of simple curves and segments of compound curves as indicated on the Contract Documents.

3. Turnouts and special trackwork shall not be superelevated.

4. Metal tags shall be installed to mark the beginning and ending points of superelevation and every 1/4-inch increment between the beginning and ending points of the spiral or superelevation transition. Bond tags to concrete with epoxy approximately 1-foot inside the outside rail to read in the direction of increasing stationing.

5. Track curve information shall be as indicated on the Contract Documents. Shop pre-curved rail shall be marked by the Manufacturer for proper installation by the Contractor.

G. Track Surface:

1. Track surface is the relationship of both rails opposite each other in profile and cross level. Track profile is the running surface along the top of the rails. Cross level is the difference in elevation between the top of heads of opposite rails measured at right angles to the track alignment. The ideal surface is a uniform profile consisting of straight gradients connected by vertical curves, with zero cross level on tangents and predetermined cross level on curves.

3.05 BALLASTED TRACK

A. Placement of Subballast:

1. Preparation:

   a. The subgrade to receive subballast course, immediately prior to subballast spreading, shall conform to the compaction and elevation tolerances specified. Additionally, subgrade shall be free of standing water and loose or extraneous material.

2. Installation:

   a. Spreading of Material:

      1) Deliver aggregate for subballast as uniform mixture and spread in layers without segregation.

      2) Any subballast stockpiled on site shall not be contaminated with underlying material when removed and placed in the final location.
3) Provide subballast material free of large and fine material pockets. Remix segregated or poorly distributed materials until uniform.

4) Moisture-condition subballast material to near optimum moisture content.

5) Subballast 6-inches and less in thickness may be spread and compacted in one (1) layer. For thicknesses greater than 6-inches, spread the subballast and compact in two (2) or more layers of uniform thickness not greater than 6-inches each.

b. Compaction: Each layer of compacted subballast material shall be not less than 95 percent of the standard density determined by WSDOT Materials Manual, Test Method T 606.

1) Thickness of finished subballast course shall not vary more than 1-inch from the indicated thickness at any point. Reshape or rework, water, and recompact subballast to achieve compliance with specified requirements that does not conform to this requirement.

3. Inspection:

a. Subballast is subject to inspection and testing by the Resident Engineer at any time between quarry production and acceptance of track. Subballast that does not conform to the Contract Documents shall be repaired or replaced, and the Resident Engineer will notify the Contractor to stop further subballasting until acceptance by the Resident Engineer.

4. Field Quality Control:

a. The Contractor shall perform tests in accordance with ASTM D6938 to determine compliance with specified requirements for density and compaction of subballast, and to determine moisture content of the installed subballast at no additional cost to Sound Transit.

b. The Contractor shall provide a minimum of one (1) sieve analysis of fine and course aggregates for every 5,000 tons of subballast delivered to the jobsite to ensure uniformity and conformance with the requirements as specified herein. Conduct sieve analysis for gradation in accordance with WSDOT Materials Manual T 27/T 11. The Resident Engineer shall be given all reports of aggregate testing.

c. During subballast installation, if the source of subballast changes, the Contractor shall perform tests and inspections as specified herein on the subballast from the new production site in accordance with the requirements as specified herein. The subballast shall have the same classification, quality, and gradation as the former subballast used. Delivery to the site shall not commence until the Resident Engineer has approved the new subballast.

d. Contractor shall string line the subballast with the Resident Engineer for subballast acceptance prior to placement of ballast.
B. Placement of Ballast Mat:

1. Preparation:
   a. Ballast mat to be installed where noted on Contract Drawings on concrete slab on grade. Prior to placement of ballast mat, concrete shall be free of debris and any damage.
   b. If the existing concrete slab does not conform to the Contract Documents, the Resident Engineer will require that the Contractor perform corrective work to meet specified requirements.

2. Installation:
   a. Contractor to install ballast mat per manufacturer specifications and as stated elsewhere in the Contract Documents.

C. Placement of Waterproofing:

1. Preparation:
   a. Waterproofing to be installed where noted on Contract Drawings on ballast bridges. Prior to placement of waterproofing, concrete shall be free of debris and any damage.
   b. If the existing concrete slab does not conform to the Contract Documents, the Resident Engineer will require that the Contractor perform corrective work to meet specified requirements.

2. Installation:
   a. Waterproofing to be placed, installed, and tested as part of waterproofing on ballast bridges requirements as stated elsewhere in the Contract Documents.

D. Placement of Ballast:

1. Preparation:
   a. Prior to placement of ballast, rutting and other damage to the subballast, ballast mat, or waterproofing, shall be corrected by the Contractor at no additional cost to Sound Transit.
   b. If the existing subballast, ballast mat, or waterproofing does not conform to the Contract Documents, the Resident Engineer will require that the Contractor perform corrective work to meet specified requirements.
   c. The Resident Engineer may take additional Samples of subballast. The Contractor shall assist and cooperate with the Resident Engineer in taking requested Samples.
   d. Subgrade settlement discovered at this time shall be corrected by placing additional subballast as stated elsewhere in the Contract Documents.

2. Installation:
   a. Uniformly distribute a base layer of ballast over the subballast, ballast mat, or waterproofing and compact before tie distribution.
b. Limit the ballast base layer to 6-inch depth, ready to be compacted, without further shaping.

c. Compact each ballast layer (lift) with not less than three (3) passes of a vibratory roller of gross weight not less than 5,000 pounds, a drum not less than 58-inches wide and not less than 42-inches in diameter. The vibration frequency shall be between 1,100 and 2,000 vibrations per minute and shall impart a dynamic impact of not less than 9 tons. Avoid damage to existing facilities including tracks, sub-drains, stub-ups, conduits, and other structures.

d. The top of the base ballast layer shall be a level, flat plane, uniformly compacted prior to cross tie distribution.

3. Inspection:

a. Ballast is subject to inspection and testing by the Resident Engineer at any time between quarry production and acceptance of track. Ballast that does not conform to the Contract Documents shall be repaired or replaced, and the Resident Engineer will notify the Contractor to stop further ballasting until acceptance by the Resident Engineer.

4. Field Quality Control:

a. The Contractor shall provide a minimum of one (1) sieve analysis of fine and course aggregates for every 1,000 tons of ballast delivered to the jobsite to ensure uniformity and conformance with the requirements specified herein. Conduct sieve analysis for aggregates in accordance with WSDOT Materials Manual T 27/T 11. The Resident Engineer shall be given all reports of aggregate testing.

b. During ballast installation, if the source of ballast changes, the Contractor shall perform tests and inspections specified herein on the ballast at the new production site in accordance with the requirements as specified herein. The ballast shall have the same classification, quality, and grading as the former ballast used. Delivery to the site shall not commence until the Resident Engineer has approved the new ballast.

c. The Resident Engineer may take additional Samples of ballast. The Contractor shall assist and cooperate with the Resident Engineer in taking such Samples.

E. Placement of Cross Ties:

1. Except as modified herein, handle, transport and store cross ties in accordance with the AREMA Manual, Chapter 30, Part 4.

a. Use only approved lifting devices that will not damage the tie.

b. Transport cross ties in a horizontal position and brace to prevent movement that could cause damage.

2. Transport cross ties from the storage area to the job site, where the ties shall be distributed and properly spaced on the compacted base layer of ballast. Space cross ties as indicated in the Contract Documents.

a. Concrete cross ties shall be spaced 30 inches center-to-center, except as noted below, measured at centerline of track or high outside rail on
curves. Tie placement frequency shall be no less than 40 ties per 100 feet of track construction, non-cumulative.

b. In curved track with radius equal to or less than 1,000 feet, concrete cross ties shall be spaced 27 inches center to center, measured at high outside rail. Tie placement frequency shall be no less than 44 ties per 100 feet of track construction, non-cumulative.

c. Adjacent to platforms concrete cross ties shall be spaced 24 inches center-to-center, measured at centerline of track. Tie placement frequency shall be no less than 50 ties per 100 feet of track construction, non-cumulative.

d. At transitions of track construction types, concrete cross ties shall be spaced, as specified on the Contract Drawings.

3. Transport switch ties to the job site, where the ties shall be distributed and properly spaced in accordance with the Contract Documents.

F. Surfacing and Aligning:

1. After the placement of rail and ties, place ballast in the tie cribs and shoulders of the track structure to restrain movement of the ties due to temperature changes in the CWR. Unload ballast in sufficient quantities that will form a high shoulder and will fill the tie cribs and provide an adequate amount of ballast for the initial track lift, plus a surplus as required to continue to hold the track in line after the initial track lift.

2. Track surfacing shall be by methods that will prevent undue bending of the rail, straining of the track joints, and damaging or loosening the spring clips or fasteners. The amount of track lift shall neither exceed 4-inches nor endanger the horizontal and vertical stability of the track. The track shall be raised so that a final lift shall not be less than 1-inch or more than 3-inches when bringing the track to the final surface. Complete final surfacing and aligning of the track after the track has been initially surfaced and aligned, fastened, and joined together by specified method.

3. Place guard rail after completion of final tamping, surfacing, and lining operation.

4. After the track has been finally raised, lined and surfaced, the rails shall be refastened within the specified zero thermal stress temperature range. Spring clips, insulators, and rail pads shall be thoroughly cleaned of dust, dirt, and grindings prior to refastening of rail. Ties and fastening devices damaged during the surfacing operation shall be replaced with new ties and fastening devices at no additional cost to Sound Transit.

5. The final track dressing shall fill cribs and shoulders with ballast to within 1-inch below the base of rail. Provide a minimum of 1-inch clearance between metallic portions of the track structure and ballast.

6. Discontinue surfacing when the ambient temperature is higher than 95 degrees Fahrenheit or the rail temperature exceeds 100 degrees Fahrenheit.

7. Perform tamping with a 16-tool squeeze-vibratory type power tamper. Control of the power tamper's tamping cycle shall ensure the maximum uniform compaction of ballast around the track. Uniformly tamp ballast under both sides of each tie, directly under each running rail for a distance of 18-inches on both sides of the rail. Tamping will not be permitted at the center of the tie, but fill the cribs with
ballast. For each tie, proceed with tamping simultaneously inside and outside both running rails on both sides of the tie.

8. Compact ballast shoulders with a vibratory shoulder compactor. Continue compacting until the ballast is firmly interlocked and the surface is true and unyielding, displaying no deformation or movement under the compaction equipment. Protect rail track components, track walls, foundations, trench drains, utilities, drainage structures, and systems or electrical conduit from damage during tamping and compaction.

9. Place and compact walkway ballast.

10. Place and compact infill ballast throughout the entire ballasted track area producing a level and uniform ballast surface.

11. Do not construct paved service aisles, access roads, or track crossings until the final surfacing and lining of the track has been completed.

G. Track Crossings:

1. Construct track crossings as stated elsewhere in the Contract Documents.

3.06 DIRECT FIXATION TRACK

A. Concrete Plinth:

1. Prepare the base concrete surface to receive the concrete plinth as a construction joint, using high-pressure water blast or other approved method. In the interval between installing coated bars and concreting the plinth, protect the coating from damage that might result from other construction work.

2. Repair slab/deck dowels where existing coatings are damaged, cracked or chipped in accordance with concrete reinforcing requirements as stated elsewhere in the Contract Documents. Replace slab/deck dowels that are beyond plinth locations, too high or too low to provide the required connection of concrete plinth.

3. Construct formwork and place reinforcing steel, direct fixation fastener or high resilient fastener inserts, and cast-in-place concrete in accordance with the requirements and intent of the Contract Documents.

B. Concrete Anchor Insert Assemblies:

1. Cast direct fixation fastener or high resilient fastener anchor bolt inserts, restraining rail fastener anchor bolt inserts, and rail anchor insert bolt into concrete to the required spacing as shown and in accordance with the Contract Documents, approved Technical Data, and the following:

   a. Clean all anchor inserts so that they are free of loose scale, grease, or other foreign matter.

   b. Coat all fastener and rail inserts with epoxy bonding agent.

   c. Use top-down construction or templates to accurately locate fasteners and anchor inserts, and anchor bolts. Positively secure the anchor inserts and bolts against displacement during concrete placement. Place inserts flush with top of concrete to plus zero-inch or minus 1/8-inch tolerance.
d. Carefully remove displaced or misaligned anchor inserts by core drilling or other approved means in a manner that prevents spalling or compromising the structural integrity of surrounding plinth, deck, slab, or invert concrete. Remove dust and loose materials from holes by compressed air or water jet and fill hole with cementitious grout. If water is used to clean holes, do not place grout until the hole is clear and dry. After grout has set and achieved 50 percent of its 28-day compressive strength, drill a hole 1/2-inch larger than the insert diameter and 1-inch deeper than insert length. Coat insert with epoxy bonding agent and fill the annular ring with cementitious grout in accordance with manufacturer's instructions. If the original enlarged cored hole is within the correct required position of the anchor insert, use the original hole. Reset anchor inserts.

e. Subject direct fixation fastener or high resilient fastener anchor inserts to the following tests conducted during the construction period at the rate of four (4) inserts per 500 inserts. Randomly select inserts to be tested. Select and test at least one (1) re-installed insert within the group of 500.

1) Restrained Pull-Out Test: Place a 5-inch by 5-inch by 1/2-inch steel plate with a hole in the center 1/4-inch larger in diameter than the insert top collar over the insert. Install an anchor bolt and apply an upward vertical load of 20,000 pounds bearing against the steel plate. Then release the load. Ensure there is no evidence of slippage or cracking of concrete or failure of bond between the insert, grout, and concrete.

2) Unrestrained Pull-Out Test: Install an anchor bolt in the insert and apply an upward vertical load of 10,000 pounds to the bolt in such a manner that no vertical load is applied to the plinth concrete within a radius of 6-inches from the centerline of the insert. Then release the load. Ensure there is no evidence of concrete cracking or failure of bond between the insert, grout, and concrete.

3) Torsion Test: Subject each of the four (4) inserts to 400 foot-pounds of torque. Ensure there is no evidence of failure of the bond between the insert, grout, and surrounding concrete.

4) Should any insert fail to meet the above tests, test four (4) additional inserts from the same 500 insert group. Failure of any of these inserts to pass the tests shall signify that the installation procedure is defective and 100 percent of the remaining lot shall be rejected. Perform additional tests as specified above and other tests as required on concrete and other materials associated with anchor insert installation to determine cause of defective installation. Do not proceed with further insert installation Work until cause of failures has been determined and a modified procedure ensuring satisfactory installation is established. Perform remedial work as described above at no additional cost to Sound Transit.

f. Handle and install the anchor inserts with care to avoid surface contamination or damage to the epoxy coating. Replace or repair damaged inserts using an epoxy coating procedure in accordance with Supplier’s instructions.
g. Finish the concrete plinth surface for the direct fixation fastener or high resilient fastener bearing seat, which includes the concrete surface area covered by the direct fixation fastener or high resilient fastener, with a uniform steel troweled cement mortar finish to provide smooth and uniform bearing surface free from voids and other defects. Verify that concrete surface is at the indicated longitudinal and cross slopes to tolerances shown on the Contract Documents. Repair unacceptable bearing seats at no additional cost to Sound Transit.

h. To protect the anchor inserts upon removal of forms or supports, install a plastic plug in each insert to seal each hole.

i. Cure concrete plinth with standard waterproof compound or damp burlap.

j. Protect installed track, drainage facilities, and systems or electrical conduits from damage and plugging. Promptly inform the Resident Engineer of any damage, Contractor is responsible to repair damage at no additional cost to Sound Transit.

C. Direct Fixation Rail Fasteners:

1. Install direct fixation rail fasteners, as specified herein, the Contract Documents, and consistent with the approved Work Plan.

2. Install direct fixation rail fasteners that are undamaged, clean and free of dirt, mortar, and other substances that could reduce performance or electrical insulation.

3. Install a single HDPE shim to separate the rail fastener from the concrete plinth surface. Install additional shims to the rail fastener to conform to the track alignment tolerances, and to compensate for differential elevations between adjacent concrete bearing surfaces. Use a nominal design thickness of the shim of 1/8-inch; however, the Contractor may vary the total thickness from 1/16-inch to 1/2-inch. Do not use more than two (2) shims to achieve the total thickness under each rail fastener. Install direct fixation track at stations with a nominal design pad thickness of 1/4-inch, using two (2) pads, for the reduction adjustment of top of rail to top of platform to conform to Americans with Disabilities Act (ADA) requirements as shown on the Contract Drawings.

4. Standard and high-resilience direct fixation rail fasteners incorporate a lateral adjustment that allows a movement of plus or minus 1/2-inch in 1/8-inch increments. This adjustment is included to facilitate alignment of the rails during construction and maintenance of the tracks. The lateral adjustment for direct fixation rail fastener shall be set in the center position, do not use more than plus or minus 1/4-inch of this adjustment during track construction. Shift shims to seat directly under the fastener.

5. Set bolts with calibrated wrenches according to the bolt tension values in accordance with Supplier’s instructions and as specified in the Contract Documents. Calibrate the wrenches by tightening, in a device capable of indicating actual bolt tension, not less than three (3) typical bolts from each lot to be installed. Adjust power wrenches to stall or cut out at the selected tension. If manual torque wrenches are used, note the torque indication corresponding to the calibrating tension and use in the installation of all bolts of the tested lot. Measure torque on nuts or bolts while in tightening motion.

6. Distribute and install direct fixation fastener or high resilient fasteners on the concrete plinths as shown in the Contract Documents and as follows:
a. In Tangent Track:
   1) 30-inches center to center measured at the centerline of track.
   2) Directly opposite each other with an offset tolerance of plus or minus 1-inch.

b. In Curved Track:
   1) 24-inches, 27-inches or 30-inches center to center measured at the high outside rail, as indicated in the Contract Documents.
   2) Radially opposite each other with an offset tolerance of plus or minus 1-inch.

c. Fastener spacings may be subject to adjustment due to structure joints, signal opening plinth gap requirements and other obstacles. Limit spacing adjustments to the range of 19-inches to 33-inches center to center. Improved track installation shall be provided by reducing several adjacent spacings, minimum of four, to achieve a required fastener spacing gap to accommodate a structure requirement, in lieu of shifting only one or two fasteners.

3.07 EMBEDDED TRACK

A. General:

1. The construction of embedded track involves the following two types of installation for embedded rail:

   a. Midblock embedded track construction using leveling beams assembly complete with welded anchor plates with weld-on shoulder and clips for fixation and utilizing rail boot and cuff for insulation. This type of embedment is typical for tracks running alongside or center of the road at location midblock between road intersections.

   b. Road intersection embedded track construction using elastomeric grout and precast concrete filler blocks for fixation and insulation. This type of embedment is typical for embedded tracks crossing road intersections.

2. The construction of embedded track shall include but not be limited to the following:

   a. Construction of rail concrete track base slab (1st pour) and surface concrete infill slab (2nd pour).

   b. Hauling construction materials.

   c. Welding of 115 RE rail for continuous welded rail (CWR) construction.

   d. Installation of track drains and trackway drain.

   e. Construction of the two types of embedded tracks.

3. Subbase preparation and concrete work shall be as stated elsewhere in the Contract Documents.

4. Electrical Circuits: Openings through the track concrete for electric wires shall be formed with PVC electrical conduits in accordance with applicable requirements as stated elsewhere in the Contract Documents.
B. Concrete Track Slab Construction:

1. The concrete track slab surface for embedded track shall be to an acceptable profile grade line elevation and located as indicated from the top of rail profile and grade on the Contract Documents.

2. Embedded concrete track base slab shall be constructed in accordance with the Contract Documents and as specified herein.

3. Holes for drainage and electrical conduit openings shall be sealed if required using elastomeric grout as specified herein or approved equal, around the conduit to provide a complete insulating barrier.

4. The elevation of the top of the concrete tolerance shall be as specified herein.

5. Slab penetrations, blockouts, and surface modifications for drainage structures, boxes and conduits shall be as shown on the Contract Documents.

6. Personnel who have responsible charge of the Work shall conduct the inspection. Defects in the base material shall be corrected prior to placement of the concrete track slab.

7. 1st pour concrete track base slab shall have a broom finish except for smooth trowel finish in some locations as shown on the Contract Documents. 2nd pour surface concrete infill slab shall be stamped and shall have skid resistant finish.

8. Expansion joints shall be no further than 60-feet apart for the two-pour system, with contraction joint at every leveling beam location. Each adjacent pour shall have a minimum time lag of three (3) days to accommodate shrinkage.

9. Expansion joints shall not be located within 10-feet of utility crossings. Coordinate expansion joint layout with utility plans.

10. When track slab shall be installed on top of existing or modified utility vaults, install expanded polystyrene board (2-inches) between track slab and the vault.

11. Electrical continuity of the reinforcing in the track slab concrete shall be as indicated on the Contract Documents and track resistance requirements as stated elsewhere in the Contract Documents.

C. Rail Boot and Cuff Installation:

1. Install rail boot and cuff as indicated on the Contract Documents.

2. Installation of rail boot and cuff shall be as recommended by the Supplier.

D. Elastomeric Grout Installation:

1. Install elastomeric grout as indicated on the Contract Documents.

2. Installation of precast concrete filler block and elastomeric grout shall be as recommended by the Supplier.

3. Before pouring or injecting elastomeric grout, application surfaces should be free of standing water and if possible surfaces should be completely dry.

4. Pouring or injecting of elastomeric grout shall provide full bearing under the base of rail and full embedment to ensure elastic separation and electrical isolation between rail and concrete slab.
5. Exposed surface of elastomeric grout embedment at road intersection pedestrian crossings and walkways shall be a non-slip or a non-skid finish.

E. Track Drain and Trackway Drain Installation
   1. Install drains as indicated on the Contract Documents.
   2. Install drains so that the drain outlets connect to drain pipes as indicated on the Contract Documents.

3.08 RAIL

A. Installation:
   1. Continuous Welded Rail (CWR):
      a. Install CWR in accordance with track rails requirements as stated elsewhere in the Contract Documents.
   2. Restraining Rail:
      a. Install restraining rail on the low rail of curved tracks as indicated on the Contract Drawings.
      b. Restraining rail shall be of bolted construction in accordance with the requirements as stated elsewhere in the Contract Documents.
      c. Restraining rail shall be fabricated of new standard 115 RE rail section in accordance with the requirements as stated elsewhere in the Contract Documents.
      d. Pre-curved restraining rail to match each curve as shown on the Contract Documents. Pre-curved restraining rail in accordance with the requirements as specified herein.
      e. Flangeway Width: 1-5/8 inches.
      f. Furnish pre-curved restraining rail end rails with tangent extensions 13-feet in length.
      g. Within the curved section of pre-curved restraining rail, furnish restraining rail end drilled with one hole in accordance with the standard drilling pattern as shown on the Contract Documents.
      h. Furnish restraining rail joints complete with 12-inch long filler block and reinforcing bars, 1/2-inch thick in accordance with AREMA Plans 325-12 for 115 RE rail, having two circular bolt holes, 1-7/16-inch diameter, 7-1/8-inch spacing, including bolts.
      i. Separator blocks for use between inside running rails and restraining rail at locations other than restraining rail joints: 4-inches in length, with circular bolt holes 1-7/16-inch diameter, furnished complete with washers. Ensure washers bear fully against the rail web and provide flat bearing surfaces for bolts. Include 1-3/8-inch diameter bolts complete with washers. Furnish and install seven (7) separator blocks for each 39-foot length of restraining rail, including tangent extensions.
      j. Furnish end blocks, two (2) per curve, 12-inches long with 1-7/16-inch circular bolt holes with restraining rail for each curve. Use end blocks in accordance with AREMA Portfolio of Trackwork Plan 504-03 except
provide flangeway width of 1-5/8-inch and no taper. Include 1-3/8-inch diameter bolt complete with washers.

k. Restraining Rail Bolts:

1) High strength type conforming to the requirements of ASTM A490 and with Class 2A and 2B thread fit.

2) Thread Length: May vary as required from that specified for structural bolts.

3) Equipped with a double coil steel spring washer, elastomeric rebound washer or equivalent spring device as a positive means of preventing the loosening of the element due to in-service vibrations.

l. Furnish restraining rail joint, end block, and separator block assemblies with filler blocks and appropriate reinforcing bars or washers wired together to prevent loss of parts.

3. Emergency Guard Rail (EGR):

a. Install Emergency Guard Rail adjacent to rail as indicated on the Contract Documents.

b. Emergency guard rail shall be fabricated and installed as shown on the Contract Documents.

c. Emergency guard rail may be second hand rail 115RE, Class 4 or better, as specified by AREMA, Chapter 4 – Rail or New Industrial Grade 115 RE rail section in accordance with the requirements specified in track rails as stated elsewhere in the Contract Documents.

d. Pre-bent fabricated EGR to match each specific track curve in short tangents as shown on the Contract Documents.

e. Guard distance shall be 10-inches, unless otherwise noted, from gauge face of rail to guard face of rail to a tolerance to meet the requirements of each different track curve.

f. Install anchor inserts for the installation of EGR throughout the limits of EGR as indicated on the Contract Documents.

g. Install anchor inserts for EGR to the specification standards of direct fixation for anchor inserts as indicated on the Contract Documents.

4. Running rail and restraining rail in curves having a horizontal centerline radius less than 500-feet or a vertical curve length less than 1,000-feet equivalent radius shall be precurved at a properly equipped facility. Precurved horizontal curve rail shall be by Manufacturer from beginning of horizontal curve to end of horizontal curve and precurved vertical curve shall be by the Manufacturer from beginning of vertical curve to end of vertical curve.

a. Perform field adjustments of precurved rail to match design radius as required

1) Such field adjustments shall be incidental to the track installation and will receive no separate payment.
3.09 SPECIAL TRACKWORK

A. General:

1. Instructions, testing, and workmanship requirements and detailed material specifications relating to the purchase and manufacture of special trackwork shall be in accordance with AREMA Plans 100-08, AREMA Specifications for Special Trackwork, unless otherwise noted herein.

2. Special trackwork layout shall be as indicated on the approved Technical Data.

3. Lubrication:

a. At the time of installation, lubricate all sliding surfaces of special trackwork assemblies with a dry film graphite lubricant. Grease switch rod clips in accordance with the Supplier’s instructions. Maintain the lubrication specified therein as necessary to ensure proper operation of all components throughout the duration of the Contract.

4. Bonded Insulted Joints:

a. Install track rail joints as stated elsewhere in the Contract Documents.

5. Installation of Special Trackwork:

a. Locate special trackwork units using stationing, coordinates, and alignment of key geometric points as indicated on the Contract Documents.

b. Assemble special trackwork using thermite welds and bolted joints as indicated on the approved Technical Data.

6. Field Quality Control:

a. To determine the acceptability of the installation, the Contractor shall make an as-built survey of the special trackwork and provide the Resident Engineer with a copy of the report. Deviations from the Contract Documents that exceed tolerances specified shall be corrected by the Contractor at no additional cost to Sound Transit.

b. Switch points shall mate and rest under the undercut stock rail and provide a continuous contact with stock rail the length of the machined point rail face adjacent to the stock rail.

c. Switch points shall bear on all slide plates as shown by grease marks and feeler gages in the thrown operating position.

d. Operation of switch points shall be unrestricted and allow for smooth switch machine operation with current draw to suit the specified switch machine.

e. Installed Turnout Tolerances:

1) Switch point location: Within 1/4-inch of engineering station.

2) Point frog, actual point location: Within 1/4-inch of engineering station.
3) Maximum switch point stagger: 1/8-inch.

4) Lead: Within 1/2-inch.

5) Layout of control switch ties at point of switch and 1/2-inch point of frog: Normal to centerline of tangent track and within 1/8-inch.

6) Spacing between switch ties under the switch and frog: Within 1/4-inch, without accumulation.

7) Spacing between the balance of the switch ties: Within 1/2-inch, without accumulation.

8) Gauge tolerance in turnout: 1/16-inch.

9) Gauge tolerance at actual point frog: Plus 1/16-inch, minus 0-inches.

7. Final Alignment and Inspection:
   a. The final surface and alignment of special trackwork shall be within the specified tolerances.
   b. Measure flangeway clearances.
   c. Throw the switch, check freedom of movement, clearances, measure force required.
   d. Throw the switch, check freedom of movement, clearances, measure force required. The Resident Engineer will coordinate testing of the switch points with the Systems contractor installing the power switch machines to make sure that the switch throw, freedom of movement, clearance, and force required will be handled by the switch machines. Failure of the components to meet these requirements shall be corrected at no expense to Sound Transit.

B. Ballasted Special Trackwork:

1. Special Trackwork cross ties in ballasted track shall be designed to accommodate future moveable point frog, anticipated means includes anchor inserts and preliminary design to support moveable point frog.

2. Placement of Switch Ties:
   a. Distribute and properly place concrete switch ties on the compacted initial layer of ballast. Space ties and align within the limits of special trackwork as indicated on the approved Shop Documents. Measurement of tie spacing in special trackwork will be made at the centerline of the tangent track, unless specifically indicated otherwise on the approved Shop Documents.
   b. Field adjustment of existing or new switch tie placement may be necessary to accommodate adjacent tracks, turnouts, joints, cable troughs, or other constraints. The Contractor shall not make field adjustments without approval by the Resident Engineer.

3. Surfacing and Aligning:
   a. Following the installation of special trackwork on the initial layer of ballast, surface the special trackwork and align as specified herein.
1) Uniformly tamp ballast under both sides of each tie, directly under each running rail and edge of special trackwork component for a distance of 18-inches on both sides of the rail. The top of the ballast section shall be approximately 1-inch below the base of the rail throughout the special trackwork unit, except in the cribs containing switch and operating rods where the ballast shall be a minimum of 2-inches below the bottom of the switch rod. The width and slope of the ballast shoulders shall conform to the appropriate sections indicated in the Contract Documents.

b. Compact ballast crib and shoulders with a vibrator shoulder compactor and as specified herein.

C. Direct Fixation Special Trackwork:

1. Construction:
   a. Clean special trackwork components of any concrete splatter or residue.

3.10 ELECTRICAL TESTS

A. As the work of this Section proceeds, perform track-to-earth electrical resistance tests at a minimum of one (1) test for every 200-feet of completed track and at special trackwork.

B. Track-to-earth electrical resistance tests shall be in accordance with track resistance testing requirements as stated elsewhere in the Contract Documents.

C. The electrical continuity of track slab reinforcing shall be tested before pouring of concrete.

D. Perform track-to-earth electrical resistance tests at ballasted track construction at a minimum of one (1) test for every 2,500-feet of completed single track. For segments of ballasted single track longer than 2,500-feet, track-to-earth electrical testing shall be conducted as the Work progresses in maximum increments of 2,500-feet.

E. Perform ground contact testing of all completed segments of ballasted trackwork after placement of ballast and prior to conducting track-to-earth electrical resistance tests.

F. At embedded midblock track, an intermediate track-to-1st pour reinforcing steel electrical continuity test shall be performed after the rail with boot has been installed and finally fastened, but before 2nd surface concrete infill slab is placed. Electrical contact between the reinforcing steel and the rail shall be removed at no cost to Sound Transit.

G. The rail boot shall be inspected and tested for breakage, discontinuity, and construction damage before placing surface concrete infill slab (2nd pour).

H. At embedded road intersection track, track-to-1st pour reinforcing steel electrical continuity test shall be performed after elastomeric grout 1st pour and 2nd pour are completed. Electrical contact between the reinforcing steel and the rail shall be removed at no cost to Sound Transit.

I. Undertake corrective measures at locations that do not meet the track-to-earth electrical resistance requirements, as specified. The corrective measures shall extend to the next tested location that meets the specified requirements. Include corrective measures requiring removal and replacement of insulating materials in the track, until the requirements are met. The corrective measures shall be made by the Contractor at no additional cost to Sound Transit.
J. Re-test the track-to-earth electrical resistance at the corrected locations, as specified.

3.11 REPAIR PROCEDURES

A. Submit a repair procedure to the Resident Engineer to assist future repair, removal, and replacement of rails installed under this Contract. The procedure shall cover at least the following items:

1. Removal methods.
2. Replacement materials including source, shelf life, and current cost.
4. Welding methods.
5. Installation methods.

3.12 CONSTRUCTION TOLERANCES

A. Base Concrete

1. The existing base structure concrete surface on which the concrete plinth is placed may vary from the design elevation within the following ranges:

   a. Tunnel (Subway): Within 1-inch
   b. Aerial Guideway and Bridge Structures: Plus 1/2-inch to minus 1-1/2-inches
   c. Concrete Slabs (Other): Within 1-inch

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<tr>
<th>Type of Track</th>
<th>Gauge (2) (Inches)</th>
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<th>Vertical Alignment Deviation (Inches)</th>
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<td>Plus or Minus 1/8-inch</td>
<td>Plus or Minus 1/8-inch</td>
<td>Plus or Minus 1/2-inch (1)</td>
<td>Plus or Minus 1/2-inch (1)</td>
</tr>
</tbody>
</table>

Notes:
1. Designed alignment and the actual constructed track position.
2. Rate of change variations in gauge, horizontal alignment, vertical alignment, cross level, and track surface shall be limited to 1/8-inch per 15-feet of track.
3. Deviation (horizontal) in station platform areas: 1/4-inch away from platform; 0-inches toward platform.
4. Deviation (vertical) in station platform areas: Plus 1/8-inch, minus 1/4-inch.
5. Deviation at top of rail to adjacent concrete: Plus 1/4-inch, minus 1/8-inch.
6. To verify that constructed track is within these tolerances a final as-built survey will be required, as specified herein.

3.13 FIELD QUALITY CONTROL

A. Alignment Survey: To determine the acceptability of the installation, the Contractor shall survey the track and provide the Resident Engineer with a copy for review. Deviations from the Contract Documents that exceed tolerances specified herein shall be corrected by the Contractor at no additional cost to Sound Transit.

1. Survey of track shall include horizontal and vertical locations of both rails every 15-feet, point of switch (POS), and point of frog (POF) including diamonds.

2. Survey results shall include actual deviations from the design, including deviation amount and direction of offset.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for manufacturing, fabricating, supply, and delivery of standard and high-strength steel rails as indicated in the Contract Documents and as specified herein.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)

2. ASTM International (ASTM)
   a. ASTM A578/A578M Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Application
   b. ASTM E10 Standard Test Method for Brinell Hardness of Metallic Materials

1.03 SUBMITTALS AND TRANSMITTALS

A. Product Data:

1. Transmit Suppliers’ product data for all rails, detailing the chemical composition and mechanical properties, including surface hardness, internal hardness, and tensile properties.

2. Transmit rail manufacturing or processing reports for all rails, listing the heat, ingot and letter for every rail including identification of the short rail, test rail, and review during the in-plant inspection and provide to the Resident Engineer. In addition include the following data:

   a. Dates of all phases of rail hardening for each charge, including head and end hardening

   b. Listing of the accepted and rejected rail in each charge

B. Manufacturer Reports:

1. Transmit a detailed description of rail hardening methods, equipment, and procedure.

2. Transmit a detailed description of ultrasonic testing methods, equipment, and procedure.
C. Qualification Statements:

1. Transmit Ultrasonic Technician qualification certification for the individuals actually conducting the testing at least 30 days before the commencement of the inspection.

2. Transmit the Rail Hardening Technician qualification certification for the individuals actually conducting the testing at least 30 days before the commencement of the inspection.

D. Work Plan: Submit a rail handling, shipping, unloading, and stacking Work Plan organized by rail, track construction type, and work

1. Provide a procedure description of rail handling, shipping, unloading, identification paint marking and stacking for each type of rail.

1.04 QUALITY

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality as stated elsewhere in the Contract Documents including inspection and testing, samples, and use of certificates of compliance.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle rails as specified in AREMA Manual, Volume 1, Chapter 4, Part 2, except as defined or modified herein:

1. Exercise care to avoid damage to rail, damaged rail shall be replaced at no additional cost to Sound Transit.

2. Load rail head up with the branding on rails facing in the same direction. Sort and load rails together according to their markings. Do not intermix rails of different markings during delivery, storage, and handling. If there are not enough rails of one marking for a full load or car, smaller groups consisting of tiers of different markings may be loaded.

3. Sort and band precurved rail according to curve radius. Load rails for the same curve marking together in the same or adjacent tiers.

B. Load rails with adequate dunnage between the tiers of rail to prevent damage during delivery, storage, and handling. At a minimum, place dunnage under the end of each rail and every 20-feet, on center, in between.

C. Stockpile or store rail within a controlled and secured area by the Contractor.

PART 2 - PRODUCTS

2.01 RAIL

A. Design of Rail

1. Rail shall be designed in accordance with the current requirements of the AREMA Manual, Volume 1, Chapter 4, Part 1, except as defined or modified herein.
B. Manufacture of Rail

1. Rail shall be manufactured in accordance with the current requirements of the AREMA Manual, Volume 1, Chapter 4, Part 2, except as defined or modified herein.
   a. Rail shall be manufactured from continuous cast blooms process.
   b. Rail shall be furnished in the as-rolled (standard and low alloy), or head hardened (on-line or off-line processes) conditions.

C. Rail for use as running rail, and in special trackwork shall be new 115 RE section. Rail shall be either standard carbon or high-strength, as indicated in the Contract Documents.

1. Special trackwork, closure rails, stock rails, and precurved rails shall be fabricated using high-strength rail.

2. Design Strings of high-strength rail to minimize the number of welds and conserve high-strength rail by minimizing the generation of unusable short rails.

D. End hardening standard and high-strength rail with Brinell hardness below 341 to between 341 and 401 Brinell Hardness per ASTM E10 in accordance with AREMA Manual, Chapter 4, Part 2.

E. Rail shall have a maximum allowable direct current (DC) resistance: No more than $8.68 \times 10^{-6}$ ohms per foot.

F. Rail shall be supplied in the maximum possible lengths to minimize welds. The minimum supplied lengths are nominal 78-feet, 80-feet, or 82-feet lengths.

G. Shorts: Maximum of 10 percent of the rails of each type.

1. Allowable short lengths for 80-feet rail lengths are 78-feet, 74-feet, and 70-feet.

2. Allowable short lengths for 39-feet rail lengths are 36-feet and 33-feet.

H. Allowable tolerances for rail lengths:

1. Drilled rail (rail used for restraining rail only):
   a. Within 7/16-inch for 39-feet rail lengths
   b. Within 7/8-inch for 78-feet rail lengths

2. Undrilled rail:
   a. Within 2-inches for all rail lengths

I. Do not end drill rails to be fabricated into continuous welded rail for joint bars or any other purpose.

J. Rails to be constructed with drilled joints:

1. As specified in the Contract Documents.

2.02 SOURCE QUALITY CONTROL

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality, as specified herein:
B. After Notice to Proceed, submit for approval by the Resident Engineer a detailed narrative explaining the quality control program and procedures to be utilized for the work and a description of the organization to be used on the Contract. Work undertaken prior to approval of the quality control program shall be at the Contractor's risk. The Resident Engineer may witness the Contractor's methods, procedures, and processes for compliance with the approved program.

C. Keep records of inspection work and provide to the Resident Engineer during the performance of the Contract; and to such other agencies and for longer periods as may be specified elsewhere in the Contract.

D. Inspection and Testing:

1. Ultrasonic Testing: Contractor is required to conduct ultrasonic rail testing by either Method 1 or Method 2, as specified herein:

   a. Ultrasonic Test Method 1:

      1) Employ a qualified independent firm or individual to witness and certify testing. The products and material incorporated into the work will be subject to inspection by the Resident Engineer, at the Contractor's and Subcontractor's facilities, place of manufacture, shipping point, and at the shipping destination. Inspection and tests by the Resident Engineer will be performed in such a manner as not to unduly delay the work.

      2) Whether or not the Resident Engineer inspects or tests any materials, the Contractor shall not be relieved from any responsibility regarding defects or other failures to meet the Contract requirements, nor shall such inspection or testing by the Resident Engineer be considered as a guarantee of acceptance of any material that may be delivered later.

      3) Employ a qualified technician to conduct testing. Provide qualification certification of each individual conducting inspection of the rail.

      4) Perform tests, analyses, and furnish the rail producer’s records of inspection and shipment as specified in the AREMA Manual, Chapter 4, Part 2 and as specified herein.

      5) Ultrasonically test rail for internal defects in accordance with ASTM A578/A578M, as modified herein:

         a) References to "plate thickness" in ASTM A578/A578M mean rail depth from head to base for measurements from the top of the rail head, or rail web width for measurements laterally through the rail web

         b) Replace "Acceptance Standards" in ASTM A578/A578M by a defect in the occurrence of one of the following readings:

         c) Complete loss of back reflection

         d) A reflection from a defect (i.e. not attributable to a reflecting surface of the rail exterior) greater than 5 percent of the back reflection
6) Reject a rail length if a defect occurs more than 3-feet from either end of the rail
   a) Defects within 3-feet of the rail end may be removed by cropping the rail segment containing the defect if the resulting rail length is to an allowable rail length increment and equal to or greater than the minimum allowable rail length. Include the reduced rail length as part of the quantity of allowable 10 percent shorts.

7) Conduct ultrasonic testing for the full length of each rail with a 1-inch diameter, 45-degree probe from the top of the rail head, directed along the length of the rail, positioned such that the rail base generates the back reflection.

8) Conduct ultrasonic testing within 12-inches of each rail end with the 1-inch diameter 45-degree probe, as specified herein, and also with a 1-inch diameter, 0-degree probe from the top of the railhead, vertically, and through the rail web, laterally. The back reflection for the lateral measurement through the rail web is the web surface opposite the probe side.

b. Ultrasonic Test Method 2:

   1) Manufacturer or Contractor may conduct 100 percent in-line ultrasonically tests with the Manufacturer’s fully computerized ultrasonic testing unit. Conduct rail testing to the requirements in AREMA Manual, Chapter 4, Part 2. Utilizing a calibration test rail of the same section as that being tested and with the following calibration reference standard:
      a) Head: 3/32-inch wide by 1/2-inch long slot
      b) Web: 1/16-inch wide by 1/2-inch long slot
      c) Base: 1/16-inch wide by 1/2-inch long slot

   2) Permanently mark indications on the rail head directly over the defect location with the percentage amplitude relative to the back reflection.

   3) Conduct all rail tests and inspections at the Manufacturer’s facilities before shipment. Assume full responsibility for testing indicated. Provide the Resident Engineer 30 days’ notice when testing is planned so the tests may be witnessed. Provide the Resident Engineer free entry at all times to the manufacturer's mill to inspect the processing and testing of rail while work on this Contract is being performed. Perform tests specified herein at no additional cost to Sound Transit.

2. End Hardening Testing:

   a. Contractor is required to conduct End Hardening Testing, as specified herein:

      1) Employ a qualified independent firm or individual to witness and certify testing. Inspection will be subject to review by the Resident Engineer, at the Contractor’s and Subcontractor’s facilities, place of manufacture, shipping point, and at the
shipping destination. Inspection and tests by the Resident Engineer will be performed in such a manner as not to unduly delay the work.

2) Whether or not the Resident Engineer inspects or tests any materials, the Contractor shall not be relieved from any responsibility regarding defects or other failures to meet Contract requirements, nor shall such an inspection or testing by the Resident Engineer be considered as a guarantee of acceptance of any material that may be delivered later.

3) Employ a qualified technician to conduct testing. Provide a qualification certification of each individual conducting inspection of the rail.

4) Select two (2) rail samples that were end hardened in accordance with the submitted procedure:
   a) Perform testing at no additional expense to Sound Transit
   b) Acceptance of the end hardening procedure and personnel will be subject to the results of specified tests and samples. Acceptance will not be made if such results do not meet specified requirements.

5) Test the two (2) samples of end hardened rail for Brinell hardness in accordance with ASTM E10 using a standard ball (10 mm) and loading (3000 kilogram-force) in longitudinal indentation increments at least two and one half times the diameters of the indentation on the rail head for a distance of 6 inches starting from the hardened end of the rail

6) Record the hardness number and location

7) The Brinell hardness number (BHN) shall not be less than 341 or more than 401 when measured at a point on the centerline of rail 1/2-inch from the rail end
   a) Untreated rail in a distance of not less than 2-inches
   b) The hardness pattern shall be uniform across the top surface of the rail head.

PART 3 - EXECUTION

3.01 FABRICATION

A. Rail:
   1. Paint identification mark for each rail type by unique color. Paint must be visible from end, top, and both sides of the rail.

B. Precurving Rail: Rail used in horizontal curves with radius less than or equal to 500-feet and/or vertical curves having equivalent radius less than 1,000-feet.
   1. Derived from straight rail before precurving.
2. Uniformly curved, such that the deviation of the interior mid-ordinate offset from the theoretical offset is within the tolerances for straight rail using the appropriate chord distance required by the straight rail specification.

3. Identified with painted identity numbering according to Contract Documents. Paint identity numbers so that they are visible from both the top and the side of the rails.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for fabricating continuous welded rail (CWR) strings and other welding of track rails, including testing and inspecting of CWR, and qualifying of welding and welders.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   a. AREMA Manual for Railway Engineering (AREMA Manual)

2. ASTM International (ASTM)
   a. ASTM E10 Standard Test Method for Brinell Hardness of Metallic Materials
   b. ASTM E164 Standard Practice for Contact Ultrasonic Examination of Weldments
   c. ASTM E709 Standard Guide for Magnetic Particle Testing

3. American Welding Society (AWS)
   a. AWS D1.1/D1.1M Structural Welding Code - Steel

4. American Society for Nondestructive Testing (ASNT)
   a. ASNT SNT-TC-1A Recommended Practice for Personal Qualification and Certification in Nondestructive Testing

1.03 SUBMITTALS

A. Quality Control Plan:

1. Submit quality control plan describing the welding procedures to be followed, including:

   a. Independent Testing Laboratory, name and qualifications of laboratory and procedures to be utilized in testing.
   b. Certification of ultrasonic and magnetic particle testing personnel.
   c. Ultrasonic inspection procedure, equipment description, and calibration methods, including the proposed frequency of calibration.
   d. Procedure for dry powder magnetic particle inspection.
   e. Inspection records for each weld for ultrasonic magnetic particle test.
f. Inspection records of each weld for straightness according to the AREMA Manual and as specified herein.

B. Pressure (Electric Flash-Butt) Welding Plan:

1. Prior to welding, submit pressure welding plan describing the welding procedures, including:

   a. Description of the welding procedure, including facilities, personnel, and list of similar completed projects.

   b. List of equipment and calibration methods, method of rail end alignment, method of rail straightening, and a schedule of lengths of rail strings to be fabricated.

   c. Welding machines performance standards as provided by the manufacturer.

   d. Requirement to attach a hard copy printout recorder to each welding machine to record rail movement and current impulses on the form: Attach forms “Record of Field Welds”, a copy of which is attached to the end of this Specification. Submit a record of machine performance for each weld to the Resident Engineer. If the record indicates performance that is not in conformance with the approved plan, the weld will be considered defective and shall be rejected at no cost to Sound Transit.

   e. Working layout or configuration drawings for the pressure welding machine and the proposed method and equipment for handling and laying CWR: Include reference data where the proposed equipment and laying method were previously successfully used.

   f. Details of the equipment and procedure proposed for straightening welds if required. Include reference data where the proposed straightening equipment and method were previously successfully used.

   g. Supplier’s recommended procedure for welding standard and high-strength rail.

   h. Proposed types and locations of environmental controls.

   i. Proposed schedule for welding operations, including duration of welding, CWR distribution, and duration of environmental controls.

C. Thermite Welding Plan:

1. Prior to welding, submit thermite welding plan describing welding procedures, including:

   a. Description of the welding procedure, including facilities, personnel, and list of similar completed projects.

   b. List of equipment and calibration methods, method of rail end alignment, method of rail straightening, and preliminary plan of thermite welds.

   c. Detailed specification of the proposed method and exact procedure.

      1) Comply with the weld kit Supplier’s instructions

      2) Include the name of the weld kit Manufacturer.
D. Thermite Weld Samples: Before beginning welding, submit two (2) qualification test welds and results as specified herein, using the welding machine, the approved procedures and the Supplier’s instructions.

E. Details procedures and working drawings for laying and anchoring CWR to the Resident Engineer.

1.04 QUALITY ASSURANCE

A. Qualifications:

1. Installers:
   a. Employ welding crews to prepare samples in accordance with the Contractor’s accepted methods and procedures for rail welding.
      1) Supervisor of each welding crew: trained and certified by the manufacturer supplying the weld kits and/or pressure welder to perform rail welding.
      2) Each welding crew: perform at least one of each type of the sample welds. Prior to performing welds in the specified Work each crew must be qualified as specified herein.

2. Independent Testing Laboratory:
   a. Employ an Independent Testing Laboratory to test sample pressure and thermite welds. Submit the certified test results to the Resident Engineer. Approval of the pressure welder, weld kit, weld specification, and welding crews will be dependent upon the sample welds satisfying the test requirements as specified herein.
   b. Testing Technician:
      1) Certified in accordance with ASNT procedure SNT-TC-1A, Level II or III
      2) Tested in accordance with ASNT procedure SNT-TC-1A, Level II or III to ensure ability to calibrate the equipment and detect defects in rail
         a) Conduct test with the standard IIW calibration blocks, DSC Blocks and calibration rail as specified herein serving as the test specimens.
         b) Technician shall be able to locate all the holes in the calibration rail by ultrasonic testing.
         c) Test will be observed by an independent technician provided by Sound Transit, certified in accordance with ASNT procedure SNT-TC-1A, Level II or III and experienced in ultrasonic examination of rail welds.
         d) Failure to pass this test will result in the disqualification of the technician.

B. Preconstruction Testing:

1. Check rail for end straightness before welding. Examine both ends and tops of rails using a three (3) foot metal straightedge, measuring deviations from straight
with a metal taper gauge. Do not weld rails which exceed the tolerances in AREMA Manual Chapter 4, Part 2 or 3.

2. Qualification Pressure Welds Fabrication:
   a. Before beginning welding, perform three (3) qualification welds of one (1) high-strength to high-strength rail, one (1) standard to standard rail, and one (1) high-strength to standard rail in accordance with as specified herein, using the proposed pressure welding plan, machine, procedures and the Supplier’s instructions.
   b. All qualification welds are required to pass as specified herein, before beginning construction.
   c. The Resident Engineer will select rails for the three (3) pressure weld qualification samples.
   d. Testing of Sample Welds: Employ an Independent Testing Laboratory to perform the following testing:
      1) Magnetic Particle Test: ASTM E709
         a) Rail temperature: below 800 degrees Fahrenheit.
         b) Acceptance criteria: Particles form regular longitudinal pattern indicating homogeneity of the weld and freedom from defects, surface irregularities and internal discontinuities.
      2) Ultrasonic Testing: per Article 1.04.B.4
      3) Dynamic Test:
         a) Perform one (1) dynamic test from sample welds that have passed the ultrasonic test.
         b) Supported sample rail weld on 36-inch centers with the weld located between supports as shown in Figure 2.
         c) Apply repeated loads with two hydraulic rams.
         d) Apply loads to the rail alternatively at Points A and B.
         e) Vary loads from zero to 44,400 pounds in the approximate shape of a sine curve.
         f) Apply loads for 2,000,000 cycles where application of load at Point A and then at Point B constitutes one (1) cycle.
         g) Measure rail deflection every 500,000 load cycles at Point A and recorded to the nearest 0.001-inch.
         h) Monitor loads with load cells placed between each ram and the rail head.
            i) Calibrate load cells prior to commencing the test program.
            i) Acceptance criteria after 2,000,000 cycles:
i) No evidence of weld failure by bending.
ii) No weld deflection exceeding 0.065-inch during the test.

4) Slow Bend Test:
   a) Perform one (1) slow bend test from sample welds that have passed the ultrasonic test.
   b) For test procedures comply with AREMA Manual Chapter 4, Part 3.
   c) Acceptance criteria:
      i) Minimum 3/4-inch deflection.
      ii) Minimum 125,000 pounds per square inch modulus of rupture.

5) Hardness Test:
   a) Perform one (1) hardness test from sample welds that have passed the ultrasonic test.
   b) Longitudinally cross-section for a distance of 4-inches each side of the weld.
   c) Macrotech.
   d) Brinell-hardness test with a 3000 kilogram load with a steel ball 10 mm in diameter.
   e) Location: vertically and horizontally on the longitudinal section in the top 3-inches in 1/2-inch increments for 3-inches each side of the centerline of the weld to determine the hardness in the heat affected zone.
   f) Acceptance criteria:
      i) Uniform decrease in hardness coincident with parent rail within a maximum of 2-inches from center of weld.
      ii) Brinell hardness numbers (BHN) between 340 and 390 on the standard ball scale throughout weld affected zone.

6) Should any qualification rail welds fail to satisfy as specified herein, either the welding process or the welding crew, or both, will not be permitted on the project. Should any supervisor of the welding crew be replaced during the work, requalify the welding crew under the new supervisor is required.

3. Qualification Sample Thermite Welds Fabrication:
   a. Before beginning welding, perform three (3) qualification welds of one (1) high-strength to high-strength rail, one (1) standard to standard rail, and one (1) high-strength to standard rail in accordance with as specified herein, using the proposed thermite welding plan, machine, procedures and the Supplier’s instructions.
b. All qualification welds are required to pass as specified herein, before beginning construction.

c. The Resident Engineer will select rails for the three (3) thermite weld qualification samples.

d. Field test of thermite production welds:

   a) Reject welds with surface cracks.

2) Magnetic Particle Test: ASTM E709
   a) Rail temperature: below 800 degrees Fahrenheit.
   b) Acceptance Criteria: Particles form regular longitudinal pattern indicating homogeneity of the weld and freedom from defects, surface irregularities and internal discontinuities.

3) Ultrasonic Testing: per Article 1.04.B.4

4) Slow Bend Test:
   a) Perform one (1) slow bend test from sample welds that has passed the ultrasonic test.
   b) For test procedures comply with AREMA Manual Chapter 4, Part 3, Section 3.10.
   c) Acceptance criteria:
      i) Minimum 1/2-inch deflection.
      ii) Minimum 125,000 pounds per square inch modulus of rupture.

4. Ultrasonic Testing: ASTM E164, with the procedure and equipment specified herein:

   a. Acceptance criteria: Free from defect or flaw giving a reflected display of greater than 20 percent of distance-amplitude correction curve at calibration level, or as listed in Table 1.

<table>
<thead>
<tr>
<th>TABLE 1 MINIMUM ACCEPTANCE LEVELS (DECIBELS)</th>
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<tbody>
<tr>
<td>Weld Thickness (inches) and Transducer Angle</td>
</tr>
<tr>
<td>Reflector Severity</td>
</tr>
<tr>
<td>5/16 to 3/4</td>
</tr>
<tr>
<td>70°</td>
</tr>
<tr>
<td>Large Reflectors</td>
</tr>
<tr>
<td>Small Reflectors</td>
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<tr>
<td>Minor Reflectors</td>
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b. Incorporate the following in the test procedure:

1) Scanning level: positive 20 decibel minimum.

2) Scan rail in a zigzag pattern-twisting probe, on one side of the weld only at a rate not exceeding 6-inches per second, so that
the full weld is scanned. Overlap each pass a minimum 10 percent and scan rail longitudinally.

3) Calibrate equipment at the start and end of each day’s work, and at least every four (4) hours during examination, and hourly checks with DSC blocks. If any point on the distance-amplitude curve has been changed by more than 20 percent, void and re-examine all results since last calibration check. If the curve has moved on the sweep line by more than 5 percent, re-examine all non-complying welds since last calibration check.

4) When a reflection of greater amplitude than the acceptance criteria is found, scan around the full perimeter of the weld from both sides, to ensure full weld coverage and determination of size, type, and location of discontinuity.

5) Make permanent trace recording of discontinuity indications.

6) Paint the rail web at non-conforming welds on both sides across the weld.

c. Use the following equipment for ultrasonic testing and document on test report form:

1) Ultrasonic, pulsed echo, instrument:
   a) Type normally used for inspection of rails with calibrated decibel gain control of minimum 2 decibel increments.
   b) Operate in the range 1-5 MHz, with CRT screen and scale.
   c) Capable of detecting a 3/64-inch discontinuity 6-1/2-inches below top of rail.

2) Calibrated paper tape recording attachments: to record accurately the CRT screen indications when a non-complying weld is located.

3) 2.25 MHz angle beam transducers: 1/2-inch by 1-inch at 70 degrees and 45 degrees.

4) High viscosity couplets of good wetting characteristics.


6) DSC Blocks of rail steel for calibration checks.

7) Calibration Rail: 115RE rail, 18-inches long with a 3/64-inch diameter round bottom hole 6-1/2-inches below top of rail and in which other 1/8-inch diameter flat bottom hole patterns have been drilled as shown in Figure 3.
   a) Ultrasonic Test Report Form:
   b) Records 20 inspected welds per sheet.
   c) Include the location of the weld in track, the results of the ultrasonic inspection including size of defects found in
the head, web or base of rail, shape identity and location of all reflections, trace record, the results of the visual inspection, name of inspector, and other information noted on Figure 1 Record of Field Welds.

PART 2 - PRODUCTS

2.01 WELDS

A. Rail shall be welded by the following two (2) methods:

1. Pressure Weld: Weld rail outside the limits of special trackwork into continuous strings using the electric flash-butt pressure welding process.

2. Thermite Weld: Only at locations where it is impractical to perform Pressure Welds and for joining continuous welded rail strings.

B. Assess the number of rails to be welded under this Contract and the number of welds that can be made by any one welding process, based on the information contained in the Contract Documents.

2.02 MATERIALS

A. Rail for Continuous Welded Rail:

1. Furnished in accordance with track rails requirements as stated elsewhere in the Contract Documents.

B. Thermite Welds:

1. Suppliers: Form thermite type rail welds utilize one (1) of the following brands of rail welding kits or an approved equal:


2. Rail welding kits for welding head hardened rail: conform to the Supplier's instructions and recommendation for such work.

3. Prior to selecting the thermite weld kit brand, obtain from the weld kit Supplier's confirmation in writing that the weld finish after grinding as specified herein is obtainable and guaranteed.

PART 3 - EXECUTION

3.01 FABRICATION

A. Continuous Welded Rail (CWR) strings:

1. Lengths:
   a. Longest practical to fabricate and handle.
   b. As required by the track alignment, bolted joint location, and worksite access.
2. Develop a schedule of the placement of rail by location in track:
   a. Consist of a schedule of lengths and designations of welded rail strings to be fabricated and proposed location in track.
   b. Indicate which strings or which portions of strings will be high-strength rail.
   c. Indicate the locations of the proposed field cuts, if any.
   d. Minimize thermite welds between standard rails and high-strength rails.
   e. Designation of the location of rail strings:
      1) Clearly identify location in track by line, survey stationing, track, and rail.
      2) Marked on the web of both end rails of each string with paint suitable for application to steel in exterior service.
      3) Unique identification for each rail string coordinated with the welding schedule indicating the location of each rail string by rail and track.

3.02 INSTALLATION

A. Fabricate ends of CWR strings with a single hole to facilitate handling. Cut off holes with rail saw or abrasive cutting disc at least 3-inches from the hole prior to welding to another rail. Do not torch cut.

B. Handling and transporting CWR shall conform to the requirements of AREMA Manual, Chapter 5, Part 5. Bumping and striking the rail during handling or laying shall not be permitted. Use rollers to facilitate transporting and avoid damage to rail, track appurtenances, and facilities.

C. Running rail shall be field drilled for restraining rail installation at locations shown on the Contract Drawings.

D. Do not place welds, pressure or thermite, within 10-feet of track rail joints.

E. Unless indicated otherwise, locate thermite welds so that they do not occur at the following locations:
   1. Within 13-feet of a thermite weld in the same rail.
   2. On ballasted or direct fixation track within 200-feet of aerial guideway abutment.
   3. Within 20-feet of a change of track construction type other than that described above.

F. When abutting CWR strings where cutting is required to fit and where the option of cutting standard rail or high-strength rail CWR exists, cut the standard rail CWR string.

3.03 LAYING CONTINUOUS WELDED RAIL

A. Laying, clamping, and fastening CWR shall be according to the following procedure:
   1. Place the CWR on direct fixation fastener rail seat and concrete ties in accordance with the approved working drawings and as specified herein.
   2. Rail Temperature
a. A record of the rail temperature and the information specified herein shall be recorded by the Contractor at the time of rail anchoring and furnished to the Resident Engineer.

1) Location by track name, station, and rail.
2) Date and time.
3) Rail weight and section, mill brand, year and month rolled, and heat number of the end rails in each CWR string.
4) Length of CWR string in feet.
5) Air temperature, rail temperature, and approximate weather conditions.
6) Rail end gap to nearest 1/16-inch.
7) Adjustments applied to obtain zero thermal stress.

3. Determine rail temperature by means of AREMA standard rail thermometers as specified in Chapter 5, Part 6, Specifications and Plans for Track Tools, of the AREMA Manual. The Contractor shall furnish the Resident Engineer with six (6) rail thermometers identical to the one to be used by the Contractor.

a. Place two (2) rail thermometers on the shaded side of the rail base next to the web and leave in place until no changes in the readings are detected, but no less than 10 minutes.

b. Take the average of the two temperature readings at the time of adjusting the gap between rail ends.

4. If the rail temperature deviates from the specified zero thermal stress range, fastening or anchoring of rail shall cease until the rail temperature returns to within the specified range and the rail has been vibrated to relax localized stress build-up.

B. Gap: During rail laying, determine the gap between CWR strings and between CWR and bolted rail by using the equation:

\[ G = (t-T)LK + Q \]

Where:

G = Rail gap in inches.

\( t \) = zero thermal stress temperature in degrees Fahrenheit.

\( T \) = Average actual rail temperature at time of laying in degrees Fahrenheit.

\( L \) = One-half the sum of lengths of CWR string being laid and the preceding CWR string.

\( K \) = Coefficient of thermal expansion for rail steel (0.000078-inch per foot per degree F).

\( Q \) = Rail gap as required by manufacturers of field weld kit in inches. For bonded insulated joints, \( Q \) equals the end post thickness.

C. Dutchman: Insert a dutchman at the time the rail is being laid to prevent damage to the rail ends during rail laying, ballasting, and other operations requiring passage of on-track equipment over the rail joints.
1. The dutchman, equal in length to G minus 1/2-inch where G is determined by the formula herein, shall be inserted after the rail has been laid, except that no dutchman shall be inserted if the computed rail gap G is less than 1-1/2-inches.

2. Remove the dutchman prior to anchoring and when the rail temperature results in a calculated closure of the rail gap.

D. Install the rail and clamp to produce zero thermal stress in the rail at a temperature between 90 degrees Fahrenheit to 105 degrees Fahrenheit. Tunnel rails more than 300-feet from portals shall be between 55 degrees Fahrenheit to 70 degrees Fahrenheit and within 300-feet from portals shall be treated as exposed rails.

1. Zero thermal stress in CWR may be achieved by heating, cooling, vibrating or pulling the rails, or a combination thereof.

2. When zero thermal stress is obtained, begin anchoring immediately.
   a. The stress within the rail shall remain within the specified zero thermal stress range during installation of joints.

3. Methods for artificially obtaining zero thermal stress shall be subject to the Resident Engineer's review prior to use.

4. Once zero thermal stress has been obtained, maintain the correct rail gap until the rail is fully anchored.

5. Vibrators used for relieving internal rail stresses shall be of a type not to damage the CWR.

6. CWR shall not be struck with objects that might damage the rail.

E. The installation of rail anchoring as described on AREMA Manual, Chapter 5, Part 4 Track Construction, is not required, anchoring is provided by the longitudinal restraint characteristics of the rail fastening spring clip.

1. Install the fasteners when the temperature of each rail in a track is within the allowable range specified herein and shall be within 5 degrees Fahrenheit of the opposite rail anchoring temperature.

2. Prior to placing on-track equipment on newly laid rail, secure the rail in a manner that will prevent damage to the rail and track material.

3. Move equipment over partially secured track in such a manner as to prevent damage to structures and trackwork materials.

4. Temporarily fasten newly laid rail at the specified gauge at every 10-feet on tangents and on curves having a radius greater than 500-feet:
   a. On curves having a radius of 500-feet or less the temporary fastening shall be at least every 5-foot interval.

5. Remove rail fastening spring clips at the time of CWR temperature adjustment.

F. When a joint is made between clamped CWR strings, the rail gap shall be as specified. If the gap is not within the recommended tolerances for the joint, unclamp the CWR strings for 300-feet each side of the rail gap, and readjust each CWR string for 300-feet within the specified zero thermal stress temperature range. Reclamp the CWR before the joint is made. If the recommended rail gap cannot be obtained in this manner, unclamp one of the strings entirely, move, length-adjust, and reclamp so that the specified rail gap is obtained. If the Contractor elects to use a mechanical means of adjusting the rail for
clamping, the method and equipment proposed shall be subject to review by the Resident Engineer.

G. After the lengths of CWR strings are adjusted for the zero thermal stress temperature vibrate them to relieve internal rail stresses, and fully anchor by complete spring clip application. Perform rail vibration with a mechanical device producing a frequency of 900 to 1,000 Hertz and a force of 160 pounds per cycle acting on the head of the rail. The method the Contractor uses to adjust the rail shall be subject to review by the Resident Engineer. The use of hydraulic machines or other “rail stretchers” in such a manner that may concentrate stresses in the end section of the rails will not be allowed.

H. Final rail fastening with zero thermal rail stress shall not proceed until the track installation meets the track construction requirements as stated elsewhere in the Contract Documents.

3.04 PREPARATION OF RAIL

A. Rail Ends:
   1. Cut square and clean by means of rail saws or abrasive cutting wheels in accordance with AREMA Manual, Chapter 4, Part 2, Section 2.1 Specifications for Steel Rails. Do not torch cut rails. Recut rail ends more than 1/32-inch out of square.
   2. Inspect and verify no steel defects, dents, or porosity before welding.
   3. End finished in a method that does not metallurgically or mechanically damage.

B. Straightness:
   1. Conform to the AREMA Manual, Chapter 4, Part 2, Section 2.1 Specifications for Steel Rails, for straightness.
   2. Straighten rails cold in a hydraulic press or roller machine to remove twists, waves, and kinks until they meet the surface and line requirements specified herein. Submit method to be used for permanent straightening to the Resident Engineer for approval.
   3. If rail is unable to be straightened permanently, cut back a sufficient distance to achieve the required alignment. Remove burrs.

C. Orient rail sticks before entering aerial guideway or tunnel for continuous welded rail strings so that the rail brands are on the field side when placed in final track position.

D. Weld shop pre-curved rail in place in the track.

3.05 CONSTRUCTION

A. Pressure (Electric Flash Butt) Welding:
   1. Conform to the AREMA Manual, Chapter 4, Part 3, Section 3.11 Specification for Fabrication of Continuous Welded Rail except as modified herein.
   2. Performed using a portable electric flash-butt welding plant or a mobile welding machine designed for rail welding:
      a. If the pressure weld machine suffers a period of malfunctioning or major repair, or when the welding crew is replaced, perform two (2) additional test welds. Re-qualify the welding machine or the new crew only after two (2) acceptable welds are produced as specified herein.
3. Saw or cut mismatched or jagged rail ends with an abrasive rail cutter. Do not mate mismatched or jagged rail ends by flashing.

4. Remove rail scale down to bright metal in areas where the welding current-carrying electrodes contact the rail. Grind down raised rail brands in electrode areas. Reject the weld and adjacent rail for a distance clearing the electrodes if, in the areas of electrode contact, less than 95 percent of the mill scale is removed. Examine electrode contact areas for evidence of electrode burn. Reject the weld where metal is displaced or where the oxidized areas exhibit checks or small cracks and cut the rail back clear of the electrode burn.

5. Forge welds to the point of refusal to further plastic deformation and to a minimum upset of 1/2-inch, with 5/8-inch as standard.

6. If flashing on electric pressure (flash butt) welds is interrupted, because of malfunction or external reason, with less than 1/2-inch of flashing distance remaining before upsetting, reclamp rails in the machine and initiate flashing again.

7. Whenever possible, grind rail immediately following welding while at an elevated temperature. When grinding must be done at ambient temperature, take care to avoid grinding burns and metallurgical damage.

8. Align head of rail in the welding machine:
   a. Vertical alignment: Provide for a flat running surface. Align rails such that any difference of rail heights occurs in the base.
   b. Horizontal alignment: Divide the difference in the width of rail heads equally on both sides of the head. If the difference, when divided, exceeds 0.040-inch, place 0.020-inch of the difference on the gauge side and the remaining differences on the field side (Brands on field side).
   c. Horizontal offset: Do not exceed 0.040-inch at the head and/or 0.125-inch at the base.

9. Surface and Gauge Misalignment Tolerances: AREMA Manual, Chapter 4, Part 3, Figure 4-3-23 Tolerances for Inspection of Welded Rail New and Mainline Relay Rail.

10. If, at any time, seven (7) or more of a series of 12 consecutive welds made on one (1) machine exceed 75 percent of the stated surface misalignment tolerances shut down that machine and adjust before continuing work.

11. Cut out any re-welds beyond the heat-affected zone of the previous weld.

12. Weld Finishing:
   a. A finishing deviation of the rail head’s top surface for the parent rail section shall not exceed plus 0.010-inch of the lowest rail.
   b. Sides of the rail head: Within plus 0.010-inch, minus 0.000-inch of the parent section.
   c. Top and bottom of the rail base: Within 0.010-inch of the lowest rail.
   d. Web zone (including the underside of the head, the web, and both fillets on each side): Within plus 0.090-inch to plus 0.010-inch of the parent section. Finish grind to eliminate all cracks.
e. Eliminate notches created by minor offset conditions, twisted or misshaped rails by minimum grinding to blend the variations.

f. Remove fins on the weld due to grinding or shear drag prior to final inspection.

13. One handling hole may be made in each end of a CWR string. Paint ends of rails containing such holes orange and cut off during track construction.

B. Thermite Welding

1. Join CWR rail sections in track in the field by thermite welding. Electric flash butt welds by the portable plant may be substituted for thermite weld connecting CWR strings only.

2. Thermite weld placement shall be limited to special trackwork locations, and the locations specified herein.

3. Do not weld rail ends containing bolt holes or handling holes. Cut off rail ends containing such holes at least 4-inches from bolt prior to welding during track construction.

4. Preparation of Rail Ends:
   a. Either saw-cut or grind at right angles to the rail to provide a smooth and clean surface.
   b. Grind clean the surface of the rails for a length of approximately 6-inches from the end of the rails to remove all grease, dirt, loose oxide, oxidized metal, scale, and moisture.
   c. Remove branding, burrs and lipped metal which would interfere with the fit of the mold.

5. Head Alignment:
   a. Comply with the AREMA Manual
   b. Weld gap at the time of thermite welding: recommended by the manufacturer of the weld kit:
      1) If the rail gap is larger than the manufacturer’s recommended gap after the rails have been adjusted for zero thermal stress, then remove sufficient rail from one or both rails to permit insertion of a rail not less than 13-feet long which shall provide the recommended gaps at each end for field welding.
      2) If the rail gap is smaller than the manufacturer’s recommended gap after the rails have been adjusted for zero thermal stress obtain the recommended gap by sawing a piece from one rail.

6. Preheat rail ends prior to thermite welding. Preheat to a sufficient temperature and for sufficient length of time as indicated in the approved welding procedure to ensure full fusion of the weld metal to the rail ends without cracking of the rail or weld.

7. Postheat thermite welding by leaving the mold in place after tapping for sufficient time to permit complete solidification of the molten metal and proper cooling to prevent cracking and provide a complete weld with proper specified hardness and ductility.
8. **Weld Finishing:**
   a. After removing the mold, use rail shears to trim upset weld metal.
   b. Complete any heavy grinding of the weld while the weld is still hot from welding.
   c. Grind weld to the following tolerances:
      1) Top, field and gauge side of the rail head: Within plus 0.010-inch minus 0.000-inch of the parent section.
      2) The remainder of the rail weld: The base riser break off area shall be ground flush with the weld collar. Other than the smoothing of the base riser break off area, the as cast geometry of the thermite weld shall be left intact.
   d. Eliminate notches created by minor offset conditions, twisted or misshaped rails by minimum grinding to blend the variations.
   e. Remove protrusions and gouges in the welded area. Blend into the rail contour by grinding in a manner that will eliminate fatigue crack origins.
   f. Remove defects visible to the unaided eye by grinding.
   g. Do not use grinding pressure that will overheat the rail surface.

9. Inspect thermite welds ultrasonically as specified herein.

10. Reject welds, as specified herein, Defective Thermite Welds. Repair welds as specified herein.

3.06 **FIELD QUALITY CONTROL**

A. **Production, Inspection, and Testing of Pressure Welds**

1. Use a chart recorder to monitor significant welding parameters. Identify each weld in each string and the rail schedule designation for each string with a notation to indicate the beginning and ending of each CWR string. Calibrate each recorder used daily. Recordings shall become the property of Sound Transit at the time the welded rail is released for installation.

2. Inspect pressure welds by the dry powder magnetic particle method in accordance with ASTM E709. Subsequently, inspect pressure welds ultrasonically as specified herein.

3. Inspect pressure welds in accordance with the AREMA Manual and as specified herein.

4. Replace defective pressure welds immediately during production. Repair other defective weld findings as specified in herein.

5. Measure the hardness of the weld on the head of the rail in the center of the weld and the heat affected zone and verify it is equal to the Brinell hardness of the parent metal with a tolerance of plus or minus 30 Brinell Hardness Numbers. Reference the Brinell hardness of the parent metal from the rail test records provided by the mill/rail manufacturer. The Resident Engineer will randomly select one weld out of each 10 for Brinell Hardness testing by the Contractor’s approved Testing Technician.
6. Employ an independent testing laboratory to perform weld testing at the Contractor's expense. The testing service and their testing program and procedures are subject to approval as specified herein.

7. Employ the independent testing laboratory to certify whether or not each weld meets the quality acceptance criteria detailed and record their findings as to acceptability or rejection of the welds. Submit independent testing laboratory reports directly to the Resident Engineer.

8. Identify Pressure Welds and Rail Strings: At the completion of welding each string of CWR, submit a record to the Resident Engineer documenting production of the string. Include all the heat numbers of the rails in the string, the number of welds in the string, the heat numbers of rail on each side of welds that have been cut out and re-welded, a record of machine performance for each weld, and reports for magnaflux and ultrasonic testing. Bind reports in pad or notebook form for ease of handling and retention as permanent record.

B. Defective Thermite Welds:

1. Determined as follows:
   
a. Quality or finishing alignment not in accordance with as specified herein.
   
b. Show a response at any level that is identified as a crack or lack of fusion.
   
c. Show a response that exceeds the primary reference level.
   
d. Show a response that is less than 50 percent of the primary reference acceptance level.
   
e. Welds that show a response greater than 50 percent but that do not exceed the primary reference level are acceptable, provided that the following apply:
      1) The defects are evaluated as slag or porosity.
      2) The largest defect does not exceed 0.180-inch in its largest dimension.
      3) The total area of the defects does not exceed 0.009-square inch.
      4) The sum of the greatest dimension of defects in a line does not exceed 3/8-inch.

3.07 REPAIR/RESTORATION

A. Pressure welds rejected during final track inspection or testing by Rail Defect Car or thermite welds rejected during inspection or testing shall be removed and re-welded if possible, or replaced with at least a 13-foot rail welded in its place by two (2) thermite welds as specified herein.

B. Special Thermite Welds:

1. Should a defective thermite weld replacement using an inserted piece of rail and two (2) welds not be practical because of limitations due to precurved rails or adjacent special trackwork parts, cut out the defective weld and replace it with a special wide thermite weld (up to 2 .75-inches). Prior to using in track, test and accept special weld as specified herein.
3.08 FIGURES

A. Figure 1 - Record of Field Welds
B. Figure 2 - Dynamic Testing of Rail Welds
C. Figure 3 - Calibration Rail

END OF SECTION
SECTION 34 11 16 – FIGURE 1
RECORD OF FIELD WELDS

DATE: ____________________________
TIME: ____________________________
TRACK DESIGNATION: ____________________________
LOCATION: STA. ________ TO STA. ________ (LT.RT)
RAIL SECTION: __115RE__ OTHER: ____________________________
MILL BRAND: ____________________________
YEAR ROLLED: ____________________________ (AHEAD) ____________________________ (BACK)
HEAT NUMBER: ____________________________ (AHEAD) ____________________________ (BACK)
TYPE OF RAIL: HEAT-TREATED CONTROL-COOLED (CIRCLE)
RAIL CUT REQUIRED: _____(YES)_______(NO)
MANUFACTURER OF FIELD WELD KIT: ____________________________
AIR TEMPERATURE: ____________________________
RAIL TEMPERATURE: ____________________________
WEATHER CONDITION: ____________________________
RAIL GAP (NEAREST 1/16 INCH): ____________________________
TRACK ALIGNMENT AND CONSTRUCTION: ____________________________

(Curve, Tangent, Grade, Etc.)

NAME OF ENGINEER OR REPRESENTATIVE PRESENT: ____________________________
NAME OF CONTRACTOR’S FOREMAN PRESENT: ____________________________
NAME OF MANUFACTURER’S REPRESENTATIVE PRESENT: ____________________________

(Initialed by those present)

RECORDER: ____________________________
SECTION 34 11 16 – FIGURE 2
DYNAMIC TESTING OF RAIL WELDS

DYNAMIC TEST-LOADING ARRANGEMENT/MOMENT DIAGRAM

Moment Diagram For
44,400 Pound Load
Over Point A

Moment Diagram For
44,400 Pound Load
Over Point B
SECTION 34 11 16 – FIGURE 3

CALIBRATION RAIL

END OF FIGURES
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing, fabricating, delivering and installing joint bars including: bonded insulated joints, factory prefabricated bonded insulated joint plug rails. Bonded insulated joints lengths and sections within the turnouts and diamond crossing will be sized by the special trackwork Supplier, but meet the requirements as specified herein.

B. All insulated joint locations outside the limits of special trackwork shall be factory prefabricated bonded insulated joint plug rails.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   a. AREMA Manual for Railway Engineering (AREMA Manual)
   b. AREMA Portfolio of Track Work Plans (AREMA Plans)

2. ASTM International (ASTM)
   a. ASTM F3125/F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions

3. The Society for Protective Coatings (SSPC)
   a. SSPC SP 10 Near-White Blast Cleaning

4. Association of American Railroads (AAR)
   a. AAR Manual of Standards and Recommended Practices

1.03 SUBMITTALS

A. Submit Technical Data, including shop drawings, manufacturer details, and installation instruction for all rail joint types within Work.

B. Transmit Installation Procedures Plan per track rail joint type, including:

1. Installation crew.

2. Installation procedures.

3. Recommended bolt tensioning.

4. Specified CWR rail gap and proposed procedure for maintaining the gap during installation of bonded joints.
5. Transmit Bonded Insulated Joints Testing: Provide test results documentation as required for the Work as specified herein.

C. Submit Electrical Resistance Tests and include track (NB, SB, EB or WB), joint location (station), position (left or right) and compliant results.

1.04 QUALITY ASSURANCE

A. Certification:

1. Tests certified by an Independent Testing Laboratory as approved by Resident Engineer.

2. Supplier’s certification: Detailed description of the Supplier’s proposed quality control program for manufacturing the bonding adhesive used in the bonded insulated joints, including how it is regulated, maintained, and monitored.

B. Qualifications:

1. Installers, Each Crew (and Foreman):

   a. Installation Crew and Foreman require pre-qualification before installing bonded joints.

      1) Pre-qualified by testing two (2) sample bonded joints fabricated by the crew

         a) Samples shall be fabricated in track and tested in longitudinal compression test as specified herein.

         b) Failure of a test sample disqualifies the Foreman and, at the discretion of the Resident Engineer, the entire crew or any crew member.

         c) Assign a new Foreman and crew personnel, then repeat the qualification procedure.

PART 2 - PRODUCTS

2.01 JOINT BARS:

A. Shaped to fit 115 RE rail with high resilient fasteners. Only toeless joint bars are acceptable for use.

   1. Hole locations: As shown in the AREMA Manual, Chapter 4 and as shown on the Contract Drawings.

B. Bolts: 1-inch diameter.

C. Bonded insulated joint plug rails: 19-feet and 6-inches in length with a 9-feet and 4-inches short end and a 10-feet and 2-inches long end.

D. Rail: Rail for the bonded insulated joint plug rails shall be 115 RE High-Strength rail in accordance with AREMA Manual, Chapter 4.

2.02 BONDED INSULATED JOINTS:

A. Manufacturers: Use bonded insulated joints of one of the following types or an approved equal:
1. The "Allegheny" joint as supplied by L.B. Foster.
2. The "Portec Bond" toeless joint as supplied by L.B. Foster.
3. Other brands will be considered as approved equal only if they successfully pass the tests specified herein.

B. Furnish bonded insulated joint kits complete with bars, end posts, bushings, washers, pin bolts, collars, and adhesive as recommended by the Supplier.

C. Joint bars:
   1. Provide full face contact.
   2. Conform to the configuration of 115 RE rail, and the Bonded Joint Clearance Envelope 115 RE (see Figure 1, herein).
   3. Fabricated from quenched carbon-steel as specified in the AREMA Manual, Chapter 4, Part 3.
   4. Height: Within a tolerance of plus or minus 1/64-inch of the dimensions indicated on the accepted Technical Data.
   5. Length: Within plus or minus 1/8-inch of the dimension shown on the accepted Technical Data.
   6. Straightness: Within plus or minus 1/32-inch adjacent to the rail.

D. Insulation material:
   1. Pre-bonded to the inside face of the joint bars, smooth with no stamping or branding.
   2. High pressure and laminated design.
   3. Impervious to oil, grease, and water.
   4. Electrical resistance characteristics: Equal to or greater than fiber insulation meeting the requirements of the AAR Manual, Part 14.5 and the Electrical Resistance Test, as specified herein.
   5. End posts: 3/16-inch thick, and not extend below the base of the rail.

E. Pin Bolts:
   1. Use to fasten bonded insulated joints for 115 RE rail together.
   2. Use six pin bolts per joint.
   3. Meet the chemical composition and mechanical property requirements of ASTM F3125/F3125M.
   5. Collars: Tension type made of low carbon steel.
   6. Driven with a special driving tool for the pin bolts:
      a. Capable of partial swaging of the collars to allow for some adjustment during the bolting process.
b. Capable of swaging the collar into angular locking grooves, forming the collar into the size and shape recommended by the Supplier before the pin tail breaks.

c. Capable of producing the minimum installed fastener tension recommended by the joint Supplier.

7. Bolt holes: Sized in accordance with the bonded insulated joint Supplier’s recommendation.

8. Washers:
   a. Placed between the joint bars and the pin’s head and collar if a bolt hole’s diameter is larger than 1-3/16-inches.
   b. ASTM F436M hardened washers.

F. Adhesive:
   1. Shelf life of 1 year when stored in a location protected from the weather at a temperature which may vary from 40 degrees F to 90 degrees F. Replace adhesive at no additional cost to Sound Transit if the adhesive is found to be defective within 1 year from the date of delivery.

2.03 SOURCE QUALITY CONTROL

A. Bonded Insulated Joint Test Requirements: Do not commence testing before Technical Data and installation procedures have been accepted by the Resident Engineer.

1. Test three (3) bonded insulated joints, in order and as specified herein; Equivalent tests achieving the specified results on the exact same joint, rail, and installed by the same crew will be acceptable if tests are within 2 years of performing the Work.

   a. Longitudinal Compression Test:
      1) Assemble bonded insulated joint in accordance with Supplier’s instructions on two pieces of 115 RE rail, each 2-feet long.
      2) Saw the joint assembly in half through the end post. Perform the sawing in a manner that will prevent overheating, and damage to the epoxy bond. Cut perpendicular to the centerline of the top of the rail with a tolerance of plus or minus 1 degree.
      3) Fabricate a device so that the reaction on the sawn end occurs only at the face of the joint bar when a longitudinal load is applied at the centroid of the rail at the opposite end.
      4) Apply loads longitudinally in increments of 25,000 pounds. Maintain each load increment constant until the longitudinal deflection of the rail ceases before increasing the load to the next increment. Increase the load in these increments until a total load of 600,000 pounds, or failure occurs. Record the load and differential movement between the rail and the joint bars at each increment of loading, measured to 0.001-inch.
      5) Acceptance Criteria:
         a) Show no indication of slippage before a compressive load of 600,000 pounds is applied to the joint.
b) Magnitude to the differential movement no more than 1/8-inch in any direction.

c) Relative position of rail and joint bar at the completion of the test, after the load on the rail has been released within 1/8-inch of its original location.

b. Electrical Resistance Test:

1) Support the rail on dry, non-electrical conducting material.

2) Apply 500 volts dc to the rail on either side of the bonded insulated joint for a duration of 3 minutes, measure the actual current flow through the joint to the nearest 0.1 microampere and record.

   a) Acceptance Criteria: Minimum resistance is 10 megohms.

3) Apply a potential of 50 volts ac to the rail on either side of the joint for a duration of 3 minutes for each increment of measurement for frequencies from 20 hertz to 10 kilohertz. Measure the impedance after 3 minutes with an accuracy of plus or minus 2 percent and record for each frequency.

   a) Acceptance Criteria: Minimum impedance is 10,000 ohms.

c. Dynamic Test:

1) Assemble bonded insulated joint in accordance with Supplier’s instruction on two pieces of 115 RE rail (see Figure 2 herein).

2) Support sample rail on 36-inch centers with the weld located between supports (see Figure 2, herein).

3) Apply repeated loads with two hydraulic rams.

4) Apply loads to the rail alternatively at Points A and B.

5) Vary loads from zero to 44,400 pounds in the approximate shape of a sine curve.

6) Apply loads for 2,000,000 cycles where application of load at Point A and then at Point B constitutes one cycle.

7) Measure rail deflection every 500,000 load cycles at Point A and recorded to the nearest 0.001-inch.

8) Monitor loads with load cells placed between each ram and the railhead.

9) Calibrate load cells prior to commencing the test program.

   a) Acceptance Criteria after 2,000,000 cycles:

      i) No evidence of joint failure by bending.

      ii) No joint deflection exceeding 0.065-inch during the test.
10) Other methods of testing the joint dynamically may be submitted to the Resident Engineer for acceptance. The moment diagram generated by other methods shall meet or exceed as specified herein.

d. Additional Post Tests:

1) Repeat Electrical Resistance Test as specified herein and meet the acceptance criteria.

2) Repeat Longitudinal Compression Test as specified herein and meet the acceptance criteria.

PART 3 - EXECUTION

3.01 JOINTS - WELDED, BONDED, INSULATED

A. Use portable electric flash butt weld or thermite welded joints to connect CWR strings together in accordance with welded track rails requirements as stated elsewhere in the Contract Documents.

B. Use thermite field welded joints in special trackwork to connect switch, frog, and closure rails together in accordance with welded track rails requirements as stated elsewhere in the Contract Documents.

C. Bonded insulated joints shall be as specified herein.

D. Locate bonded insulated joints as indicated on the Contract Drawings and approved special trackwork shop drawings.

E. Install bonded insulated joints in accordance with Supplier’s instructions.

3.02 PREPARATION

A. Cut rails square and clean by means of either saws or abrasive cutting disks.

B. Deburr and remove rough edges for bolt holes.

C. Field end harden rails, other than high-strength rails, as stated elsewhere in the Contract Documents that are not end-hardened at the mill.

1. Remove joint bars and associated insulating materials from rail ends during end-hardening process.

D. Bevel rail ends as shown on AREMA Plans No. 1005-03.

E. Clean the end 21-inches of the web, bottom of head, and top of base of each rail of foreign materials, loose rust, and scale.

F. For bonded joints, clean to near white metal in accordance with SSPC SP 10. Grind raised mill marking within the 21-inch distance flush with the web.

3.03 INSTALLATION

A. Accurately space holes for bolting of rail and drill with a rail drill in accordance with the requirements or AREMA Manual, Chapter 4, Part 3.

1. Drill cylindrical holes of specified diameter for the size of the bolt required through and perpendicular to the web of the rail.
2. Use a template as a drilling guide. In no case shall a joint bar be used for this purpose.

B. Joints, including insulated joints, shall not be located opposite each other on the same track. Joints shall be staggered at least 2-feet, but not more than 2-feet 6-inches, from the joint on the opposite rail, unless otherwise noted on the Contract Drawings or approved by the Resident Engineer.

C. Bonded Joints:
   1. Install bonded joint at the locations indicated and as required by the signal system. Position joint so that center of the joint is approximately centered between rail supports.
   2. Calibrate bolt-tightening equipment.
   3. Install joint in accordance with the Supplier’s instructions and the following:
      a. Alternate directions of bolt insertion.
      b. Ensure that there is no contact between joint bars or bolts and rail fasteners.

3.04 FIELD QUALITY CONTROL
   A. Test the resistivity across the insulating components of each joint after the installation and all welding has been completed in the field. Repeat the Electrical Resistance Test as specified herein and meet the acceptance criteria specified.

3.05 FIGURES
   A. Figure 1 - Bonded Joint Clearance Envelope
   B. Figure 2 - Testing of Bonded Insulated Joints

END OF SECTION
SECTION 34 11 19 – FIGURE 1
BONDED JOINT CLEARANCE ENVELOPE

NOTE:
NOT INTENDED TO EXCLUDE USE OF STANDARD AREA JOINT BARS IN YARDS.
SECTION 34 11 19 – FIGURE 2
TESTING OF BONDED INSULATED JOINTS

END OF FIGURES
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing all labor, materials, and equipment for the designing, manufacturing, testing, fabricating, shipping, and unloading of switch point rails, stock rails, frogs, diamond crossing, restraining rail, guard rails, guard rail plates, switch plates, frog plates, standard plates for single rail, lead rails, closure rails and bonded insulated joints.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   a. AREMA Manual for Railway Engineering (AREMA Manual)
   b. AREMA Portfolio of Trackwork Plans (AREMA Plans)

2. ASTM International (ASTM)
   a. ASTM F3125/F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions
   b. ASTM B633 Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
   c. ASTM D2240 Standard Test Method for Rubber Property – Durometer Hardness
   d. ASTM E10 Standard Test Method for Brinell Hardness of Metallic Materials
   e. ASTM E94 Standard Guide for Radiographic Examination

3. American Welding Society (AWS)
   a. AWS D1.1/D1.1M Structural Welding Code - Steel

4. American Institute of Steel Construction (AISC)
   a. AISC Steel Construction Manual

5. American Society of Mechanical Engineers International (ASME)

1.03 SUBMITTALS

A. Submit detailed special trackwork Technical Data, including shop drawings, bill of materials, and supporting drawings for all special trackwork and components.
B. Prior to the delivery of special trackwork, the Contractor shall submit a plan for special trackwork grouping, packaging, handling, loading, and transportation.

C. Transmit complete list of Suppliers and Manufacturers for all special trackwork and components, including Quality Control Program for each.

D. Transmit installation and maintenance instructions for all special trackwork and components.

E. Transmit rail inspection results in accordance with track rails requirements as stated elsewhere in the Contract Documents.

F. Transmit frog depth hardening tests results.

G. Spare Parts: Furnish spare parts in accordance with Article 2.08. Additional spare parts and changes to Article 2.08 are subject to review by Sound Transit.

1.04 QUALITY ASSURANCE

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality as stated elsewhere in the Contract Documents, including inspection and testing, samples and use of certificates of compliance.

1.05 DELIVERY, STORAGE, AND HANDLING

A. The entire special trackwork elements and assembly shall be match marked, banded and palletized as specified herein prior to shipment.

B. Carefully handle rail and special trackwork components to prevent damage, do not drop or strike rails and components.

C. For components pre-assembled for inspection prior to shipment, including frogs, diamond crossing, and other components shall ship in complete partial subassemblies. Contractor is responsible for shipping special trackwork subassemblies in sizes that can be delivered to proposed locations, possibly through tunnels, under and on bridges.

D. Ship small loose parts in secure containers shipping boxes or kegs. Do not ship in cardboard boxes or pallets that are not fully banded. Loose items for shipping will not be accepted.

E. Clearly mark or tag assembled parts, pallets, bundles, boxes, and kegs in the appropriate turnout identification color with the following: Identify items contained, Contractor's name, shipping date, number of pieces, destination, gross weight, turnout designation, and special trackwork unit for which parts are intended.

PART 2 - PRODUCTS

2.01 GENERAL

A. Fabricate special trackwork components out of new materials as indicated on Contract Drawings, approved Shop Drawings, and in accordance with AREMA Manual, AREMA Plans, and as specified herein.

B. Insulate special trackwork to restrict stray current leakage.

C. Construct special trackwork with zero cant throughout the installation.

D. Switch point:
1. Mate and rest under the undercut stock rail.

2. Provide a continuous contact with stock rail the length of the machined point rail face adjacent to the stock rail.

3. Bear on slide plates as shown by grease marks and feeler gages in the thrown operating position.

E. Track and Special Trackwork Tolerances: Refer to track construction tolerances as stated elsewhere in the Contract Documents and as specified herein.

2.02 RAIL

A. Running rail for switch, frog, stock, closure, guard and lead rails for special trackwork and precurved:

1. New 115 RE in accordance with AREMA Manual.

2. Head hardened to meet the hardness requirements of high strength rail, as specified in AREMA Manual, Chapter 4, Part 2, Section 2.1 – Specifications for Steel Rails.

3. Accompanied by Supplier’s records of rail inspection as described in AREMA Manual, Chapter 4, Part 2, Section 2.1, Article 2.1.14 – Acceptance.

B. Guard rails for frog and diamond crossing:

1. 115 RE Section machined and drilled to guard length indicated in Contract Documents and accepted Technical Data.

2. Head hardened to meet the hardness requirements of high-strength rail, as specified in AREMA Manual, Chapter 4, Part 2, Section 2.1 – Specifications for Steel Rails.

C. Stock rail: Undercut to suit the 5100 (Samson) switch point design. Use stock rails of sufficient length to provide thermite welds clear of the switch area.

D. Lead rails and closure rail: Lengths and curvatures based upon the geometric data shown on the Contract Documents and Technical Data.

E. Switch point rail for special trackwork: As indicated, fit the curved switch point for lateral track movement with a manganese protective wear point.

1. Switch point rail for mainline track construction: Floating heel block design.

2. Throw of switch: Distance through which the points of switch rails move sidewise and measured along the center line of the No. 1 switch (throw) rod shall be 4-3/4-inches.

3. Curving and planing of switch points and undercutting of stock rail: properly bind the switch points into the stock rail within the full length of the required side-planing length. Design switch point to allow adjustment of the “throw of switch” from 4-1/4-inches to 4-3/4-inches width and to gradually narrow the throw width to a flangeway width of 1-5/8-inches (minimum) after the switch points are in either thrown positions.

2.03 SWITCH APPURTEANCES

A. Switch points:
1. 5100 (Samson) switch point design in accordance with AREMA Plans, No. 221-08 with the exception they shall be single reinforced and as specified herein.

2. Uniform riser design with runoff beyond the heel of switch.

3. Constructed of reinforcing bars, ½ and 1-1/4-inches thick, drilled and assembled to the switch points by square head bolts, hex nuts and cotter pins. Pin bolt assembly is not acceptable.

B. Direct fixation track construction turnouts:

1. Switch rods shall be insulated vertical design and in accordance with AREMA Plans, No. 222-08.

2. Equipped with vertical rod type MJ clips with bolts, security locknuts and cotter pins.

3. Adjustable switch rods:
   a. Throw: 4-inches to 5-inches.
   b. Clearance between the top of switch rods and base of stock rails: 3/16-inch maximum.
   c. Project under and beyond the stock rail base in both thrown positions.

C. Floating heel block assembly (Two-Bolt): Design in accordance with AREMA Specifications for Special Trackwork, Article M3, Carbon Steel Castings.

D. Rail brace supports:

1. Adjustable design, preferably with boltless connection, at locations indicated.

2. Type A as shown on AREMA Plans, No. 224-08 or an approved equal.

3. Modified as required to permit the installation of switch point heaters under the head of the stock rail.

E. Ensure switch point stops:

1. Are of sufficient height to bear against the supporting stock rails when points are in the thrown positions.

2. Are in accordance with AREMA Plans, No. 221-08.

F. Joint Bars: Refer to track rail joints requirements as stated elsewhere in the Contract Documents.

G. Track bolts, hex head bolts, square head bolts, security locknuts, and washers:


H. Metal components:

1. Corrosion-resistant and consistent with strength and hardness requirements.

2. Not brittle, and able to withstand handling at minus 20 degrees Fahrenheit.

3. Sufficiently ductile to withstand installation and maintenance activities. For iron castings use ductile iron.
I. Spring clips: Right-hand mounted, and considered part of the switch plate or direct fixation plates.

J. Direct Fixation Special Trackwork Switch Plates as specified in requirements as stated elsewhere in the Contract Documents.

2.04 FROGS

A. Used for turnouts or crossing diamonds.

B. Solid Manganese steel as specified in AREMA Specifications Article M2.

C. Solid Manganese steel turnout frogs: Designed by the special trackwork supplier.

D. Solid Manganese steel crossing frogs: Designed by the special trackwork supplier.

E. Solid Manganese steel frog castings: Depth hardened as specified herein.

F. Frog plates: Designed by the special trackwork Supplier.

2.05 FROG GUARD RAILS

A. Manufactured in accordance with the Contract Documents.

B. 115 RE Section, machined and drilled to guard rail lengths as shown on the Contract Documents and Technical Data.

C. Furnished with the accessories as indicated on the Contract Documents:
   1. Separator Blocks: Malleable or ductile iron

D. Flangeway:
   1. 1-5/8-inches, fully adjustable to increments of a maximum of 1/8-inch.
   2. Width: 1-1/8-inches to 1-5/8-inches, when used with unworn rail.
   3. End block and separator blocks: Allow adjustment of the flangeway width.

E. Frog Guard Rail Bolt:
   1. High strength, conforming to the requirements of ASTM A325, ASTM A490 or Grade 8, and class 2A and 2B thread fit.
   2. Thread length may vary as required for the specified bolts.
   3. Use a steel spring washer or equivalent spring device as positive means of preventing the loosening of the element due to in-service vibrations.

F. Fasteners: Designed as indicated in the Contract Documents.

2.06 RAIL FASTENER ASSEMBLIES

A. Spring Clips:
   1. Boltless, threadless and resilient design able to recoil back into shape after bending.
   2. Permit removal of the rail, switch or frog without the removal of plate’s anchor bolt assembly.
2.07 TRACK JOINTS
   A. Thermite welded and bond insulated as indicated on the Contract Documents and Technical Data.
   B. Install bond insulated joints in accordance with requirements as stated elsewhere in the Contract Documents.

2.08 SPARE PARTS
   A. As specified in the Contract Documents.

2.09 SPECIAL TRACKWORK TURNOUTS
   A. As indicated on the Contract Documents and approved Technical Data including materials necessary to provide a complete installation and the required turnout spare parts as specified herein.

2.10 SWITCH LUBRICANT
   A. Lubricate with dry graphite, insulating film-type such as Dixon 500, Whitmore Easy Switch, Superior Graphite Co. or an approved equal as instructed by the Supplier.

PART 3 - EXECUTION

3.01 ASSEMBLY
   A. Rail Precurving:
      1. Perform precurving of rail to industry frog and switch shop procedures in accordance with the track centerline radii shown on the Contract Documents and approved Technical Data. Precurve rail such that after curving the base of rail lies level or flat when positioned on the switch or tie plate. Do not use the fastening to draw the base down.
   B. Rail Cutting, Drilling, and Beveling:
      1. Cut rails square and clean by means of rail saws or abrasive cutting wheels in accordance with AREMA Manual, Chapter 4, Part 2.
      2. Where required, drill rail ends for 36-inch, 6-hole bonded insulated joint as shown on approved Technical Data and in accordance with the AREMA Manual Chapter 4, Part 1. Grind drilled bolt holes to remove sharp edges.
   C. Frog Depth Hardening:
      1. Explosive depth hardened or otherwise treated castings in accordance with the AREMA Specifications, Article M2.7, except attain a minimum Brinell hardness of 370. After the castings are hardened, employ an approved Independent Testing Laboratory to inspect each casting as follows:
         a. Visually inspect or penetration test for cracks, flaws, or porosity.
         b. Test hardness in accordance with ASTM E10.
      2. On Technical Data specify the procedures to be used in the depth hardening process, the portions of each frog that are to be depth hardened, and the Brinell hardness pattern that the Manufacturer normally achieves with such procedures.
3. Submit reports of the tests and inspections to the Resident Engineer for review. Repair defective castings damaged as a result of this inspection as specified herein. Re-harden castings rejected for lack of hardness at no additional cost to Sound Transit. Defects detected in the immediate wheel running surfaces of the castings will be rejected and not be repaired. Replace non-repairable castings at no additional cost to Sound Transit.

4. Repair defects in the castings in accordance with the AREMA Specifications Article M2.6, as modified herein. Repair defects only by shielding manual arc welding or semi-automatic arc welding, in accordance with AWS D1.1/D1.1M. Use only manganese filler to repair defective areas.

5. After weld repairs, employ an approved Independent Testing Laboratory to re-inspect the repaired areas of the castings in accordance with ASTM E94 and determine the acceptance of the castings.

6. The tolerance for Brinell hardness is minus 10 Brinell points. The maximum hardness is unlimited, but subject to metallurgical steel structure detriment to the product.

3.02 SHOP ASSEMBLY AND INSPECTION

A. Prior to shipment, completely assemble each turnout and diamond crossing with direct fixation fasteners installed and all fastenings shop tightened. Mount each turnout in a uniform plane throughout the length of the turnout or crossing to allow inspection and measurement. Assemble components designed for field welding to final alignment using appropriate fasteners and clamps.

B. Place special trackwork fasteners at locations shown on the Contract Documents and approved Technical Data. Mark base of rail with paint to indicate design location of plates or fasteners.

C. Provide the Resident Engineer with templates to check flangeways, rail end drilling, and switch rail planing. Design templates such that using the templates will be easy and quick, requiring only one (1) person for the operation and not change in dimension due to temperature, moisture, or time.

D. Completely install bonded insulated joints designated on the Contract Documents and approved Technical Data for shop fabrication in accordance with Supplier instructions prior to inspection. Install bonded insulated joints without adhesive.

E. No bracing is allowed to hold components to proper gauge during the shop inspection process other than permanent gauge plates. Grind smooth rail branding and rail web surface within 2-feet of rail ends at joint bars and sand blast prior to placement of joints.

F. Note approved variations from the dimensions, lengths, or angles shown on the previously approved Shop Drawings on the final Shop Drawings submitted for subsequent installation.

G. Paint identification on the web of rails, clear of joint bar area, at both ends according to the rail layout details shown. Paint rail joint members on the head of each rail at every joint. Do not confuse installation identification numbers with internal shop work order numbering system. Only paint installation numbers on track items.

H. For inspection of the turnout switches on direct fixation track, include the operation (hand thrown at the first temporary switch rod) to confirm function and proper position of switch points in relation to the stock rail (switch points should nestle with stock rail within the full length of the required side planing length), switch point stops, and proper opening at separation of heads.
I. Check switches and moveable part in both thrown positions for conformance with the approved switch and frog geometry. Verify tolerances meet the applicable requirements as stated in the AREMA Plans, No. 1011.

J. Inspect spare parts components as listed herein, during the trackwork inspection. Position spare parts adjacent to the turnout component for inspection comparison. For identification, paint spare parts "Spare Part" with turnout data and Contract Number on both sides of the component on the rail web.

K. Notify the Resident Engineer not less than 30 days before the required date for shop inspection of the completed, assembled turnout with identification markings. Reconfirm one (1) week ahead of Resident Engineer arrival that the assembly shall be completely assembled, checked by the fabricator’s QC organization and all corrective actions taken before the Resident Engineer arrives.

L. The Contractor shall correct deviations from the Contract Documents and Technical Data that exceed specified tolerances at no additional cost to Sound Transit.

M. After satisfactory inspection and testing with the switch completed, disassemble the switch machine from the switch to the degree necessary for shipment. Package loose materials in the Supplier’s original containers.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing, testing, handling, and transporting mineral aggregate for track ballast and infill ballast as indicated on the Contract Documents and as specified herein.

B. Ballast shall be placed and installed in accordance with track construction requirements as stated elsewhere in the Contract Documents.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance of Way Association (AREMA)
   a. AREMA Manual for Railway Engineering (AREMA Manual)

2. ASTM International (ASTM)
   a. ASTM C29/C29M Standard Test Method for Bulk Density (“Unit Weight”) and Voids in Aggregate
   b. ASTM C88 Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
   c. ASTM C117 Standard Test Method for Materials Finer Than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
   d. ASTM C127 Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate
   e. ASTM C136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
   f. ASTM C142/C142M Standard Test Method for Clay Lumps and Friable Particles in Aggregates
   g. ASTM C535 Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
   h. ASTM C702/C702M Standard Practice for Reducing Samples of Aggregate to Testing Size
   i. ASTM D75/D75M Standard Practice for Sampling Aggregates
1.03 SUBMITTALS

A. Subballast Readiness Report:
   1. Prior to the placement of ballast or other construction on the subballast, the Contractor shall submit a report documenting and confirming the readiness of the subballast.
      a. The Contractor shall document the existing condition of the in-place subballast including documentation of line, grade, cross section, and compaction.

B. Ballast Structure Readiness Report:
   1. Prior to the placement of ballast, ballast mat, or other construction on the ballast structure the Contractor shall submit a report documenting and confirming the readiness of the structure surface.
      a. The Contractor shall document the existing condition of the in-place structure including documentation of line, grade, cross section, and surface quality.

C. Ballast Qualification Test Reports:
   1. Prior to the delivery of ballast, the Contractor shall submit a report documenting and confirming ballast qualifications.
      a. The Contractor shall engage an independent testing agency to test the ballast at the quarry source to ensure that the classification, quality, and gradation of the ballast at the time of delivery conforms to the specified requirements.

D. Plan for Transporting, Handling, and Placing:
   1. Prior to the delivery of ballast, the Contractor shall submit a plan for ballast transportation from the source, handling, stockpiling, and final distributing and placement of ballast: including the location of stockpiles and the identification, quantity, and handling/hauling equipment.

E. Ballast Mat Qualifications:
   1. Submit the manufacturer’s current published installation instructions and detailed written procedures. The documents shall address the following items:
      a. Identification of material to be used by product number and description.
      b. Shipping, storing, and handling.
      c. Equipment identification, operation, and maintenance.
      d. Surface preparation to attain bond.
      e. Mixing, applying, and curing.
      f. Weather conditions.
      g. Public Safety.
      h. Touch-up and repair.
i. Quality control implementation.

j. Conflicts between the manufacturer’s instruction, applicator’s procedure, and the Contract requirements shall be brought to the attention of the Resident Engineer for resolution.

1.04 QUALITY ASSURANCE

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality as stated elsewhere in the Contract Documents, including inspection and testing, samples, and use of certificates of compliance.

1.05 DELIVERY, STORAGE AND HANDLING

A. Delivery: Load only into rail cars or trucks that are in good order, tight enough to prevent leakage and waste of material, and clean and free from deleterious or any substance that may foul or contaminate the ballast.

B. Storage: If material is stock piled or stored off-site or on-site, take necessary steps to maintain ballast gradation and keep clean and free from deleterious or any substance that may foul or contaminate the ballast.

C. Handling:
   1. Handle prepared ballast at the producing plant, during shipment, and at the site so that it is kept clean and free from segregation. Ballast containing any substance that may foul or damage the ballast will be rejected.
   2. Do not make repeated passes of equipment over the same level in the stockpile area.

PART 2 - PRODUCTS

2.01 BALLAST

A. Provide prepared ballast of crushed stone, containing no carbonates or slag; composed of hard, strong, angular, and durable particles; free from deleterious substances; and conforming to the requirements of the AREMA Manual, Volume 1, Chapter 1, Part 2, except as defined or modified herein.

B. Properties:
   1. Gradation Requirements:
      a. For track ballast provide AREMA size No. 3 ballast having the following gradation:

      | Sieve Size | Percent Passing by Weight |
      |------------|----------------------------|
      | 2.5-inches | 100                        |
      | 2.0-inch   | 95-100                     |
      | 1.5-inch   | 35-70                      |
      | 1.0-inch   | 0-15                       |
      | 0.5-inch   | 0-5                        |

      Sieve analysis shall be made in accordance with ASTM C136 and ASTM C117.
b. For infill ballast, walkways, and access areas at turnouts provide AREMA size No. 5 ballast having the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5-inches</td>
<td>100</td>
</tr>
<tr>
<td>1.0-inch</td>
<td>90-100</td>
</tr>
<tr>
<td>0.75-inch</td>
<td>40-75</td>
</tr>
<tr>
<td>0.5-inch</td>
<td>15-35</td>
</tr>
<tr>
<td>0.375-inch</td>
<td>0-15</td>
</tr>
<tr>
<td>No. 4</td>
<td>0-5</td>
</tr>
</tbody>
</table>

Sieve analysis shall be made in accordance with ASTM C136 and ASTM C117.

2. Deleterious Substances: The amount of deleterious substances present in the prepared ballast shall not exceed the following limits, when performing the following specified tests:

<table>
<thead>
<tr>
<th>Test For</th>
<th>Percent By Weight</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Finer than No. 200 Sieve</td>
<td>1.0</td>
<td>ASTM C117</td>
</tr>
<tr>
<td>Clay Lumps and Friable Particles</td>
<td>0.5</td>
<td>ASTM C142/C142M-10</td>
</tr>
</tbody>
</table>

3. Flat or Elongated Particles: Particles having a length equal to or greater than five times the average thickness of the particle shall not exceed 5 percent by weight of the total.

4. Wear: The percentage of wear, when tested in the Los Angeles abrasion machine in accordance with ASTM C535, shall not exceed the following percentages:
   a. Granite: 35 percent
   b. Traprock: 25 percent
   c. Quartzite: 30 percent

5. Soundness: The soundness of the prepared ballast shall be such that, when tested in the sodium sulfate soundness test in accordance with ASTM C88, the weighted average loss shall not exceed 5 percent after five (5) cycles of the test.

6. Water Absorption: Water absorption shall not exceed 1 percent when tested in accordance with ASTM C127.

7. Unit Weight: Rodded unit weight shall be greater than 90 pounds per cubic foot, determined in accordance with ASTM C29/C29M-09.

2.02 SOURCE QUALITY CONTROL

A. The Contractor shall establish the ballast quality, grading, and washing requirements at the time of delivery to ensure that the ballast conforms to the requirements as specified herein when installed in track.

B. Test Samples: A field sample not less than 150 pounds shall be taken from the quarry of prepared ballast in accordance with ASTM D75/D75M. Test samples shall be reduced from field samples to testing size in accordance with ASTM C702/C702M.
2.03 BALLAST MAT

A. Ballast mat shall consist of natural rubber with fabric reinforcement designed to provide a reduction in the impact on structures of ground or structure-borne vibrations and in the crushing of ballast. The upper surface of the mat shall be textured to permit ballast to nest for track bed stability and shall contain synthetic elastomers for protection against attack by contaminants that may filter through ballast over time. The subsurface shall contain fabric reinforcement for strength and load distribution. Its underside shall provide a regular pattern of projections that provide load distribution, e.g. ridges, cones, etc.

B. Ballast mat material shall conform to the following requirements:

1. Minimum Capacity Axle load: 12 tons

2. Dimensions:
   a. Width no less than 48 inches not including joint overlaps
   b. Minimum Thickness: 1-1/8 inches
   c. Length: 30 feet maximum

3. Fabric (Fiberglass-coated PVC):
   a. Minimum Tensile Strength: 600 lbs/inch
   b. Elongation at Break is greater than or equal to 10 percent

4. Elastomer Properties (natural rubber unless otherwise approved)


6. Isolating Layer Minimum Thickness: 1 inch

7. Ballast Mat:
   a. Minimum Tensile Strength: 1,150 psi
   b. Elongation at Break: 125 percent
   c. Minimum Tear Resistance: 50 pounds/inch
   d. Hardness (Shore A): 50 (plus or minus 5)

8. Dynamics: Dynamic to static stiffness ratio $K_d$ related to a preload of 85 psi is equal to an allowable range between 0 and 1.5, with desirable of 1.4

9. Temperature Range: Standard quality is suitable for service where ballast mat temperatures range between minus 4 degrees Fahrenheit and plus 158 degrees Fahrenheit

C. The material used for sealing of the ballast mat joints shall be an integral extension of the top surface of the mat or separate material having strength characteristics equal to those of the top layer of the ballast mat.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Ballast shall be installed, including but not limited to preparation, inspected, and tested as stated elsewhere in the Contract Documents.

B. Ballast mat shall be installed on ballast structures and where indicated on Contract Drawings.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing, testing, handling, and transporting aggregate for track subballast as indicated on the Contract Documents and as specified herein.

B. This Section is applicable to work required for placement of new subballast, and restoration or repair of existing subballast damaged or disturbed by other work.

C. Subballast shall be placed and installed, as a part of track construction, as stated elsewhere in the Contract Documents.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. Washington State Department of Transportation (WSDOT)
   a. WSDOT Standard Specifications for Road, Bridge, and Municipal Construction
   b. WSDOT Materials Manual
      1) WSDOT FOP for WAQTC/AASHTO T 27/T 11, Sieve Analysis of Fine and Coarse Aggregates
      2) WSDOT Test Method T 606, Method of Test for Compaction Control of Granular Materials

1.03 SUBMITTALS

A. Subballast Qualification Test Reports:

1. The Contractor shall engage an independent testing agency to test the subballast at the quarry source to ensure that the classification, quality, and gradation of the subballast at the time of shipment conforms to the specified requirements. Conduct sieve analysis for aggregates in accordance with WSDOT Materials Manual T 27/T 11.

B. Plan for Transporting, Handling, and Placing:

1. Prepare a plan for proposed transporting from the source, handling, stockpiling, and final distribution and placing of subballast in track, including the location of stockpiles and the identification, quantity, and handling/hauling equipment including year, hours, and condition.

C. Subballast Compaction Testing Reports:

1. Subballast compaction testing reports shall be submitted to the Resident Engineer for review of earth moving and track construction, as stated elsewhere in the Contract Documents.
1.04 QUALITY ASSURANCE
   A. Develop and maintain a quality control program regulating methods, procedures, and
      processes to ensure compliance with standards of quality assurance/quality control as
      stated elsewhere in the Contract Documents, including inspection and test, samples, and
      use of certificates of compliance.

1.05 DELIVERY, STORAGE AND HANDLING
   A. Delivery: Load only into rail cars or trucks that are in good order, tight enough to prevent
      leakage and waste material, and clean and free of deleterious or any substance that may
      contaminate the subballast.
   B. Storage: If material is stock piled or stored off-site or on-site, take necessary steps to
      maintain subballast gradation and keep clean and free from deleterious or any substance
      that may foul or contaminate the subballast.
   C. Handling:
      1. Handle prepared subballast at the producing plant, during shipment, and at the
         site so that it is kept clean and free from segregation. Subballast containing
         any substance that may foul or damage the subballast will be rejected.
      2. Do not make repeated passes of equipment over the same level in the
         stockpile area.

PART 2 - PRODUCTS

2.01 SUBBALLAST
   A. Aggregate for subballast at the time it is deposited on the prepared subgrade or subbase
      shall conform to the following requirements:
      1. Subballast shall consist of crushed stone or gravel, free from plant matter, and
         other deleterious substances.
      2. Aggregate shall comply with WSDOT Standard Specifications Section 9-03.9(3) Crushed Surfacing Base Course.

2.02 SOURCE QUALITY CONTROL
   A. The Contractor shall perform sampling and tests of the subballast material to determine
      compliance with specified requirements. Samples will be taken from material as delivered
      to the site.

PART 3 - EXECUTION

3.01 INSTALLATION
   A. Subballast shall be placed, installed, and tested as a part of track construction as stated
      elsewhere in the Contract Documents.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for rail grinding and rail polishing.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents:
   1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
      a. AREMA Manual for Railway Engineering (AREMA Manual)
   2. International Standards Organization (ISO)
      a. ISO 3095 Acoustics – Rail Applications -- Measurement of noise emitted by railbound vehicles

1.03 DEFINITIONS
A. CPC: Specially designed rail head profile for Sound Transit’s tangent track in open track area. This rail profile offsets the running band about 0.5 inches toward the gauge side of the rail.
B. CPF: Specially designed rail head profile for Sound Transit’s tangent track in embedded track area. This rail profile provides a running band at the center of the rail head.
C. HRC: Specially designed rail head profile for Sound Transit’s curved track’s high rail. This rail profile has been designed to provide a one point conformal contact that provides for good steering to reduce flange wear and noise.
D. LOW: Specially designed rail head profile for Sound Transit’s curved track’s low rail. This rail profile is identical to the CPF, except that it extends only 35 degrees on the gauge side.
E. Right Rail: Facing the increasing track stationing number, the rail on the right side of the specified track.
F. Left Rail: Facing the increasing track stationing number, the rail on the left side of the specified track.
G. Transition Zone: A specified track section with changing the rail head profile continuously and uniformly over the whole section from one specified rail head profile at the beginning point to another specified rail head profile at the ending point.

1.04 SUBMITTALS
A. Submit equipment for rail grinding, polishing and method of operation.
B. Submit Pre-Grinding Inspection Report
1. Provide a pre-grinding inspection report prior to submitting the Rail Grinding Work Plan. Include rail profile information and rail running surface condition information for pre-grinding analysis of the rail, and clearly define rail profile conditions and rail running surface conditions. Use optical measurement equipment or equivalent technology to obtain rail profile information.

C. Submit Rail Grinding Work Plan:

1. Develop a Rail Grinding Work Plan. The Rail Grinding Work Plan shall include grinding locations, curve information, left and right rail, grinding profiles, grinding profile transition zones, number of grinding passes required, stone grit size, grinding speed, RPMs of grinding stone and total work time required for each grinding segment.

2. Provide method to achieve and verify grinding tolerances

3. Provide Safety Plan of grinding equipment within Sound Transit’s Vehicle Clearance Envelope. Include methods to protect all track and structural components from the damage caused by the grinding equipment and grinding equipment operations.


D. Submit Rail Polishing Work Plan:

1. The Rail Polishing Work Plan shall include rail polishing locations, curve information, number of polishing passes required, polishing speed, RPMs of polishing stone, stone grit size and total work time required for each polishing segment. The Work Plan shall clearly demonstrate how the tallest roughness peaks caused by the polishing grinder will be at 50 mm ± 5mm wavelengths and not between 26 – 40 mm.

2. Provide method to achieve and verify polishing tolerances

3. Polishing step shall use fine grit stones with grit size not less than 24. An alternate or equivalent means of achieving the polishing criteria may be submitted by the Contractor to Sound Transit for review and may be employed, if approved by Sound Transit.

E. Submit Rail Grinding Production Report.

1. Submit Rail Grinding Production Report at end of each shift documenting working crew, grinding locations, total grinding time for each track section, pre- and post-grinding profiles, stone size and stone grit size, grinding speed, pre- and post-grinding corrugation conditions, number of passes, and confirmation of grinding tolerances achieved.

F. Submit Rail Polishing Production Report.

1. Submit Rail Polishing Production Report at end of each shift documenting working crew, polishing locations, total time for each track section, pre- and post-polishing profiles, stone size, stone grit size, grinding speed, pre- and post-polishing corrugation conditions, number of passes, and confirmation of grinding tolerances achieved.

G. Submit System Post-Grinding Report

1. Provide a post-grinding database report that documents and analyzes field data for those areas ground in the program. The database report shall be able to be integrated with the pre-grinding database. Include in the post-grinding report an
inventory of what track was ground, the number of passes achieved, and total grinding times for each work zone. The report shall include rail roughness data demonstrating that the Grinding Acceptance Limit has been met at representative locations as agreed upon in the Work Plan approved by Sound Transit. Provide data in Excel and Word format.

H. Submit System Post-Polishing Report

1. Provide a Post-Polishing Report that documents and analyzes field data for those areas polished in the program. The report shall be able to be integrated with the pre-grinding database. Include in the post-polishing report an inventory of what track was polished, the number of passes achieved, and total polishing times for each work zone. The report shall include rail roughness data demonstrating that the Grinding Acceptance Limit has been met at representative locations as agreed upon in the Work Plan. Provide data in Excel and Word format.

1.05 MOCK-UP (DEMONSTRATION SECTION)

A. To validate the Work Plan and demonstrate the Contractor’s ability to deliver the rail grinding and polishing by constructing a demonstration section a minimum of two days prior to the scheduled beginning of grinding.

1. Utilize the exact procedure as specified in the Work Plan. Construct the demonstration section to the length of at least one complete production but not less than 500-feet. If the demonstration section does not meet the requirements as specified in the Contract Documents, submit a revised Work Plan and construct another demonstration section or sections as required.

2. The finish of the Demonstration Section shall be measured for rail roughness using the Corrugation Analysis Trolley (CAT) and the results submitted to Sound Transit for review and concurrence. Production grinding outside Demonstration Section will not be allowed until the CAT results are reviewed and accepted by Sound Transit.

3. The requirement for a Demonstration Section may be waived at Sound Transit’s sole discretion, if the Contractor submits information showing prior grinding projects in which the contractor met grinding and polishing criteria that were at a minimum as stringent as Sound Transit’s criteria or more stringent.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 GENERAL

A. Reprofile grind and polish rail in accordance with the Work Plan and applicable requirement, as specified herein and as indicated on the Contract Documents.

3.02 CONSTRUCTION EQUIPMENT

A. Rail grinding and polishing equipment shall:

1. Traverse Sound Transit track gauge, guard rail, flangeway width, curve radii, rail sections, and special trackwork components as shown in the Contract Documents without causing damage to the rail, fasteners, track structure or trackwork. Damages shall be repaired by the Contractor at no additional cost to Sound Transit.
2. Clearance for the grinding equipment shall conform to the requirements for vehicles clearances, as specified in Sound Transit Design Criteria Manual, Chapter 4, Track Alignment and Vehicle Clearance.

3. Maximum axle load of 20 tons.

4. On board monitors to continuously measure rail profile and rail roughness and provide real time feedback to the operator.

5. Measure in length in metric units and angles in degrees.

6. Obtain rail cross sectional profile.

7. Measure corrugation depth and wavelength to an accuracy of 1.0 micrometers.

8. No fewer than 8 grinding motors and be capable of creating 8 unique facets on each rail, or the equivalent capability and alternate technology.

9. Equipment shall meet the dynamic envelope of Sound Transit's tunnels.

10. Minimum achievable grinding motor angles of minus 70 degrees gauge and plus 15 degrees field.

11. Able to grind through crossings, embedded track, and turnouts.

12. Dust-collection system capable of removing materials from the grinding operation.

13. On board fire suppression equipment to meet requirements for right-of-way protection during grinding operations.

14. Spark arrest shielding to confine grinding sparks under the frame. Protect all fire-sensitive track and tunnel components, such as rubber pads underneath and around the rails, from burning caused by grinding sparks.

15. Spark arrest shielding to confine grinding sparks under the frame.

16. On-board mobile radio equipment for communication with Link Control Center.

17. Pressurized cab to prevent smoke and dust from entering the operating compartment occupied by the operators and pilot.

B. Rail grinding equipment shall have the following controls or equivalent capabilities:

1. Computer-based grinding pattern control.

2. Automated motor positioning of grinding heads.

3. Fully adjustable and automated grinding head control to accommodate multiple grinding patterns.

4. Grinding pattern changes and adjustments achieved through an onboard central control system.

5. Capable of grinding a variety of profiles and re-occurring patterns depending on varying rail wear conditions.

6. Operator and/or computer-controlled grinding-head configuration adjustment to adjust profile in tangent-to-curve grinding situations.

7. Vertical stability control of grinding heads with ability to remove rail corrugation.
8. Grinding motor load control shall be manually selected and automatically maintained.

9. Grinding patterns shall not change with curve elevation or track gauge.

10. The unit shall be capable of grinding in tight clearance areas including road crossings, special trackwork, floating slabs, pedestrian crossing and tunnels causing no damage.

11. Ability to grind only those areas required.

12. Sequencing grinding head control capability to clear obstructions, including signals equipment to allow grinding through equipment without its removal.

C. Rail Grinding Equipment Operation:

1. Constant working speed to ensure uniform grinding finish.

2. Ridges left by grinding facets shall not be so sharp as to result in the development of flow lines, spalling at edge of contact bands or induce wheel noise from a rail defect.

3. Able to stop and park on maximum 8 percent grade.

4. Able to work at a speed of not less than 3 miles per hour on maximum 8 percent grade.

5. Able to work in bi-directional operation.

6. Capable of travel speed up to 25 miles per hour.

7. Provisions for emergency coupling at either end of equipment to allow equipment removal in case of operational failure. Such as drawbar or pintle hitch. Lights for night rail travel and work, including all necessary safety and warning lights and sound devices.

8. Low noise level during grinding to allow night work in residential areas. The maximum noise level during grinding is 85 dBA at a distance of 50 feet from any portion of the grinding train.

3.03 GRINDING PROFILES

A. The following are the four grinding profiles required by this specification. Sound Transit may revise the rail grinding profiles at any time within 10 days before rail grinding is performed.

1. High Rail Curve (HRC): Profile is designed as single point conformal contact profile and shall be used on horizontal curves with radius less than 5,000-feet.

2. Low Rail (LOW): Profile is designed to promote field side rail contact and shall be used in conjunction with the High Rail Curve on the inside or low rail of a curve with radius less than 5,000-feet.

3. Contact Point Center (CPC): Tangent profile is designed to place the running band on the rail center for the purpose of spreading wear of the when and shall be used on tangent track and horizontal curves with radius equal to and greater than 5,000-feet including the spiral.

4. Contact Point Field (CPF): Tangent profile is designed to place the running band on the rail center for the purpose of spreading wear of the when and shall be used
3.04 GRINDING TOLERANCES

A. Transverse Profile:
   1. Maximum transverse profile tolerance shall be minus 0.5-millimeter to plus 1-millimeter (in relation to design profile).

B. Longitudinal Profile:
   1. Maximum top of railhead longitudinal variation (corrugation) of 0.02 millimeters over 200 millimeters
   2. Finished Surface Roughness (Ra) shall not exceed 5 micrometers on the contact location between the wheel and the rail, otherwise known as the running band. Finished Surface Roughness (Ra) shall not exceed 10 micrometers at any point on the railhead.
   3. Rail roughness in 1/3 octave bands over wavelengths of 5-millimeters to 600-millimeters shall not exceed the limits provided in Figure 1. Compliance with this requirement shall be verified over four sections, per mile of track, with a minimum length of 400-feet. The locations for the tests will be specified by Sound Transit and be included in the System Post-Grinding Report.
   4. The tallest rail roughness peak caused by the polishing. The tallest rail roughness peak caused by the polishing grinder shall be at 50 mm ± 5mm wavelengths and not between 26 – 40 mm.
   5. The limits in Figure 1 may be exceeded by a maximum of 3 decibels in no more than two (2) 1/3 octave bands over a combined length no more than 5-meters in any 100 meter section.
   6. The roughness measurements will be performed using a CAT at up to 6 points across the rail head from gage face to 60 millimeters from gage face. Location of CAT transducers to be determined by grinding mark locations and the contact band.
FIGURE 1: RAIL ROUGHNESS - GRINDING ACCEPTANCE LIMIT

Rail Roughness - Grinding Acceptance Limit

1/3 RMS Roughness, dB

1/3 Octave Band Wavelength, mm

- ISO 3095:2005
- Acceptance Limit (Grinding)
TABLE 1: RAIL ROUGHNESS – GRINDING ACCEPTANCE LIMIT

<table>
<thead>
<tr>
<th>1/3 Octave Band Center Frequency, Hz</th>
<th>Roughness (decibel ref 1 µm)</th>
<th>Roughness (micrometer)</th>
</tr>
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<tr>
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<tr>
<td>3.15</td>
<td>4.7</td>
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</table>

C. Visual Appearance:
1. Where facets are produced by the grinding operation, the maximum facet width shall be 4-millimeters on the gauge corner, 7-millimeters on the shoulder and 10-millimeters within 10-millimeters of the rail crown.
2. The grinding zone shall be blended smoothly into the parent rail.
3. The maximum variation in facet width over a 100-millimeters length of rail shall be 25 percent of the maximum width of the facet.
4. There shall not be continuous bluing in the grinding zone.

3.05 POLISHING TOLERANCES

A. Transverse Profile:
1. Maximum transverse profile tolerance shall be minus 0.5-millimeter to plus 1-millimeter (in relation to design profile).

B. Longitudinal Profile:
1. Maximum top of railhead longitudinal variation (corrugation) of 0.02 millimeters over 200 millimeters
2. Finished Surface Roughness (Ra) shall not exceed 5 micrometers on the contact location between the wheel and the rail, otherwise known as the running band.
Finished Surface Roughness (Ra) shall not exceed 10 micrometers at any point on the railhead.

3. Rail roughness in 1/3 octave bands over wavelengths of 5-millimeters to 600-millimeters shall not exceed the limits provided in Figure 2. Compliance with this requirement shall be verified over four sections, per mile of track, with a minimum length of 400-feet. The locations for the tests will be specified by Sound Transit and be included in the System Post-Polishing Report.

4. The tallest rail roughness peak caused by the polishing grinder shall be at 50 mm ± 5 mm wavelengths and not between 26 – 40 mm.

5. The limits in Figure 2 may be exceeded by a maximum of 3 decibels in no more than two (2) 1/3 octave bands over a combined length no more than 5-meters in any 100 meter section.

6. The roughness measurements will be performed using a CAT at up to 6 points across the rail head from gage face to 60 millimeters from gage face. Location of CAT transducers to be determined by grinding mark locations and the contact band.

**FIGURE 2: RAIL ROUGHNESS - POLISHING ACCEPTANCE LIMIT**

![Graph showing Rail Roughness - Polishing Acceptance Limit](https://uncontrolled.document.from.soundtransit.org)
TABLE 2: RAIL ROUGHNESS – POLISHING ACCEPTANCE LIMIT

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C. Visual Appearance:
1. Where facets are produced by the polishing operation, the maximum facet width shall be 4-millimeters on the gauge corner, 7-millimeters on the shoulder and 10-millimeters within 10-millimeters of the rail crown.
2. The polishing zone shall be blended smoothly into the parent rail.
3. The maximum variation in facet width over a 100-millimeters length of rail shall be 25 percent of the maximum width of the facet.
4. There shall not be continuous bluing in the polishing zone.

3.06 FIELD QUALITY CONTROL
A. Rail grinding and polishing production report at end of each shift documenting working crew, grinding locations, total grinding time for each track section, pre- and post-grinding profiles, pre- and post-grinding corrugation conditions, number of passes, grinding and polishing stone grit sizes and confirmation of grinding tolerances achieved.

3.07 FIGURES
A. Figure 3: HRC
B. Figure 4: LOW
C. Figure 5: CPC
D. Figure 6: CPF
FIGURE 5: CPC
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for the design, manufacture, testing, delivering, handling and storing of monoblock prestressed concrete cross ties, including insulated rail fastening components and base pads as indicated in the Contract Documents and as specified herein.

B. Two lengths of concrete crossties, with and without guard rail configurations, are:
   1. 8 feet - 3 inches cross tie.
   2. 10 feet - 0 inches cross tie.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.

1. ASTM International (ASTM)
   a. ASTM F3125/F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions
   b. ASTM A416/A416M Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete
   c. ASTM A536 Standard Specification for Ductile Iron Castings
   d. ASTM A881/A881M Standard Specification for Steel Wire, Indented, Low-Relaxation for Prestressed Concrete Railroad Ties
   e. ASTM A886/A886M Standard Specification for Steel Strand, Indented, Seven-Wire Stress-Relieved for Prestressed Concrete
   f. ASTM C31/C31M Standard Practice for Making and Curing Concrete Test Specimens in the Field
   g. ASTM C33/C33M Standard Specification for Concrete Aggregates
   h. ASTM C39/C39M Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
   i. ASTM C78 Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
k. ASTM C114 Standard Test Methods for Chemical Analysis of Hydraulic Cement
l. ASTM C143/C143M Standard Test Method for Slump of Hydraulic-Cement Concrete
m. ASTM C150/C150M Standard Specification for Portland Cement
n. ASTM C172/C172M Standard Practice for Sampling Freshly Mixed Concrete
o. ASTM C191 Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
r. ASTM C231/C231M Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
t. ASTM C289 Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
u. ASTM C295/C295M Standard Guide for Petrographic Examination of Aggregates for Concrete
v. ASTM C359 Standard Test Method for Early Stiffening of Hydraulic Cement (Mortar Method)
w. ASTM C430 Standard Test Method for Fineness of Hydraulic Cement by the 45-microm (No. 325) Sieve
x. ASTM C494/C494M Standard Specification for Chemical Admixtures for Concrete
y. ASTM C586 Standard Test Method for Potential Alkali Reactivity of Carbonate Rocks for Concrete Aggregates (Rock Cylinder Method)
z. ASTM C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
aa. ASTM C1105 Standard Test Method for Length Change of Concrete Due to Alkali-Carbonate Rock Reaction
bb. ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials
cc. ASTM D395 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension Set
dd. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers - Tension
ee. ASTM D471 Standard Test Method for Rubber Property - Effect of Liquids
gg. ASTM D573 Standard Test Method for Rubber-Deterioration in an Air Oven
hh. ASTM D732 Standard Test Method for Shear Strength of Plastics by Punch Tool
ii. ASTM D1149 Standard Test Methods for Rubber Deterioration – Cracking in an Ozone Controlled Environment
jj. ASTM D1229 Standard Test Method for Rubber Property - Compression Set at Low Temperatures
kk. ASTM D2240 Standard Test Method for Rubber Property - Durometer Hardness
ll. ASTM D2440 Standard Test Method for Oxidation Stability of Mineral Insulating Oil
mm. ASTM E122 Standard Practice for Calculating Sample Size to Estimate, with Specified Precision, the Average for a Characteristic of a Lot or Process

2. American Association of State Highway and Transportation Official (AASHTO)
a. AASHTO T 26 Standard Method of Test for Quality of Water to be Used in Concrete

3. American Concrete Institute (ACI)
a. ACI 301 Specifications for Structural Concrete
b. ACI 305 Specification for Hot Weather Concreting

4. American Railway Engineering and Maintenance-of-Way Association (AREMA)
a. AREMA Manual for Railway Engineering (AREMA Manual)

5. The Society for Protective Coatings (SSPC)
a. SSPC SP5 White Metal Blast Cleaning

1.03 SUBMITTALS

A. Technical Data: Submit Technical Data for each length of cross tie before the start of fabrication work. Include shop drawings of each cross tie and all information necessary for fabrication.

1. The Contract Drawings show the general arrangement and configuration of the work to be performed.

2. Include the dimensions, details, tolerances, materials, finishes, prestressing steel, embedded items, and fastening system components.

3. Prepare shop drawings including design calculations and other data as specified herein.
4. Include the procedures for installation and replacement of the fastener components.

B. Certificate of Experience: Transmit certification that the manufacture of concrete cross ties has minimum of five years' experience in long-line concrete cross tie production.

C. Plan for Transporting, Handling, and Placing:
   1. Transmit a plan for the method of handling, shipping, unloading, and stacking of concrete cross ties.

D. Transmit a concrete cross tie marking scheme for identification of ties.

E. Transmit production test records and other required documentation for review during the in-plant inspection and submit prior to shipment of the ties.

F. Transmit all certified test reports and certificates of compliance, as specified herein.

1.04 QUALITY ASSURANCE

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality as stated elsewhere in the Contract Documents, including inspection and testing, samples and use of certificates of compliance.

1.05 DELIVERY, HANDLING, AND STORING

A. Delivery: Ties with threaded plastic caps or plugs securely installed in threaded insulated inserts. Securely brace ties for transportation to prevent movement that could cause damage. Stack ties in a horizontal position, braced with wooden spacer blocks so that the top surface or cast-in-place hardware does not contact ties loaded above. Do not load ties higher than the top of the cars nor more than six layers deep.

B. Do not drop or skid ties. Package other parts to prevent damage during shipment and to facilitate handling. Do not mix different parts in the same package.

PART 2 - PRODUCTS

2.01 CONCRETE TIES

A. Design Requirements:
   1. Design: Contractor shall prepare the final design of the concrete ties in accordance with AREMA Manual Volume 1, Chapter 30, Part 4.
   2. Track Configuration:
      a. Standard concrete cross ties shall be designed for use in standard ballasted track with 115RE rail and 4-feet and 8-1/2-inch gauge.
   3. Operating Conditions:
      a. Multiple unit electrically propelled trains of up to four (4) cars shall operate at speeds of up to 55 miles per hour on these ties. The design axle load shall be 27,700 pounds subject to a 30 percent impact factor. Approximate annual vehicle trips shall be 356,000.
      b. The compaction of ballast under and around the tie shall be done by using hydraulic or electric activated tamping tools on a production ballast
tamper. The cross tie shall resist these tamping forces without spalling of concrete on the sides and bottom corners.

4. Environmental Conditions: Environmental conditions shall be those of the Puget Sound region including an ambient temperature range of 30 degrees Fahrenheit to 75 degrees Fahrenheit, with an extreme range from 0 degrees Fahrenheit to 105 degrees Fahrenheit and an average annual rainfall of 42-inches.

5. Design Criteria: Concrete cross ties shall be as shown on the Contract Documents and shall meet the following requirements:

   a. Concrete cross ties consist of the following components:
      1) Concrete tie complete with embedded rail fastening shoulders.
      2) Insulating elastomeric rail base pads.
      3) Spring rail clips and spring clip insulators.

   b. Design strength and electrical isolation requirements:
      1) Concrete compressive strength shall be 7,000 pounds per square inch at 28 days.
      2) Concrete cross tie designs shall be subject to acceptance testing to confirm minimum strength and electrical insulation requirements, as specified herein.
      3) In lieu of the concrete tie design acceptance testing requirements specified herein, the Contractor may submit certification from prior successful testing of an equal concrete tie design and have proven ten (10) years performance history.

   c. Protrusions: Do not use sharp angles or protrusions that are easily damaged by handling or tamping.

   d. Manufacturing tolerances:
      1) For concrete ties finish dimensions shall be plus or minus 1/4-inch on length, width, depth and chamfer.
      2) For concrete tie and fasteners track gauge shall be plus or minus 1/16-inch, exclusive of mill tolerance in rail.
      3) For concrete ties centerline of the tie shall be within 1/2-inch of the centerline of the track gauge.

   e. Rail Cant: 1 in 40, plus or minus 5, towards the centerline of the tie, except where shown in the contract documents.

   f. Rail Seat Plane: Flat smooth surface within plus or minus 1/32-inch.

   g. Differential Tilt of Rail Seats: The differential tilt in the direction parallel to the rail of one rail seat to the other shall not exceed 1/16-inch over a width of 6-inches.

   h. Protrusion of Pretensioning Tendons: 1/8-inch maximum beyond the ends of the ties.

   i. Concrete Cover for Prestressing Tendons, Ducts, and Prestressing End Fittings:
1) 3/4-inch minimum cover, measure cover from outside of embedded items to surface of concrete.

j. Manufacturing tolerances for clear concrete protection (cover) and depth of prestressing tendons:

1) Plus 1/8-inch for any two (2) rows of tendons.

2) Plus 3/16-inch for the third row.

k. Rail Clip Toe Loads: The tolerances of the ties, shoulders, rail clips, insulators, and rail seat pads shall be small enough to prevent excessive variations in the rail clip toe loads. Tolerances that affect the rail clip toe loads shall be approved by the rail clip Supplier and submitted to the Resident Engineer for approval.

l. Rail Hold-Down Components:

1) Rail hold-down assemblies shall be designed for use with 115 RE rail.

2) Rail hold-down assemblies shall be comprised of as few components as economically and technically feasible for ease of assembly, disassembly, and maintenance. The rail clips, rail seat pads, embedded shoulders, and insulators shall be furnished by the rail clip Supplier.

3) Design of the ties shall allow the rail clips to be installed and replaced in the field by one worker using hand tools. The clips and fasteners shall be a threadless design.

4) Cross ties shall have, on both sides of the rail base, a positive means of preventing more than 1/8-inch total lateral movement of the rail base relative to the fastener in case of failure or loosening of one or both rail clips. The positive means of restraint shall extend at least 3/8–inch, but not higher than 1-3/4-inches above the base of rail in the installed position.

5) Construct fastenings so that when the rail clips are removed, the rail may be lifted vertically until it is completely free of the fastening shoulder without disturbing the horizontal or vertical alignment of the shoulder or the adjacent restraining rail bracket.

m. Rail Seat Pads:

1) Provide rail seat pads compatible with the rail fastening system with a shape that provides positive means of preventing movement of the pad parallel to the rail. Use elastomer pads with a thickness of at least 3/16-inch and not more than 7/16-inch, a width identical to the distance between the shoulder faces on the rail seat (plus 0-inch, minus 1/16-inch) and a length 1-inch longer than the rail seat bearing area (plus or minus 1/16-inch). Mark pads in a permanent manner to indicate Supplier, month and year manufactured, and designation.

n. Rail Clips:

1) The rail clip shall be threadless, one-piece elastic, heat treated, alloy spring steel. One identical clip shall be used on the field and gauge side of the rail at the rail seat.
2) The clips shall be reusable after removal through repeated applications without effect on the operating performance of the system.

3) No part of the clip shall protrude below the tie surface or into the tie.

4) The clip shall not have point contact. The clip shall be such that lateral rail movements within the confines of the shoulders will not produce transverse denting, carving, or scoring of the rail base. The clip shall be such that longitudinal rail slippage will not produce overstressing, bending, twisting, or other damage to the clips, and will not damage the rail.

5) Rail clips and insulators used on rail insulated joint bars need not to be identical in design to those used on a standard rail. The clips shall clear the joint bar, shall have similar performance characteristics, shall be made by the same Supplier, and shall be installed into identical shoulders as the standard rail clip. Rail insulated joint bar dimensions for track rail joints are stated elsewhere in the Contract Documents.

o. Insulators Between Fastener Hardware and Rails:
   1) Provide keys between the insulators and the fastener hardware to prevent relative motion in any direction.
   2) The insulators shall cover the full widths of the shoulders.
   3) Except for surfaces in contact with the rail, the surfaces of the insulators shall be smooth, clearly finished and free of flash. Insulators shall be free of internal defects and cavities.

p. Rail Fastening Shoulders:
   1) Shoulders shall be threadless and shall be designed to provide and maintain proper position and alignment of the rail clip, insulator, rail seat pad, and rail base.
   2) The shoulder shall not be directly anchored to the pretensioned steel.
   3) The shoulder shall be ragged stem design to maximize the surface area and pull out resistance.

B. Materials:
   1. Cement:
      a. Cement shall conform to ASTM C150/C150M, Type II or III low alkali (less than 0.60 percent). The false set penetration, when tested in accordance with ASTM C359, shall not be less than 50-millimeters initially, 35-millimeters at intermediate times, and 40-millimeters after remix.

      b. Separate random samples of cement shall be taken each day of production to represent the cement used on each bed. Each sample shall not be less than 1 pound and shall be clearly identified with the date and bed number. Each sample shall be kept in airtight containers until the corresponding 28-day cylinder tests have been carried out and results accepted by the Resident Engineer.
c. Not more than two (2) sources of clinker or ground cement shall be used during any one month. Cement from each source shall be clearly identified and stored in separate weathertight silos. If two sources of cement are used on one bed, the tests shall be performed on the first batch of concrete made with each cement and thereafter as required. Strength tests shall also be conducted on concrete made with each type of cement.

d. Cement mill certificates shall be provided weekly by each Supplier and shall continue the results of the following tests on cement delivered during that week:

1) Fineness by air permeability (ASTM C204).

2) False Set (ASTM C359) - Penetration at three (3), five (5), eight (8), eleven (11) minutes and after remix.

3) Setting Time (ASTM C191).

4) Compressive Strength (ASTM C109/C109M) at 1 day, 3 days, and 7 days.


6) Residue on 325 mesh sieve (ASTM C430).

e. At least once during every three (3) months, a randomly chosen sample of cement from each source used shall be analyzed for alkali content in accordance with ASTM C114 by an Independent Testing Laboratory.

2. Fine and Coarse Aggregates: Provide aggregates free from deleterious substances and conforming to the requirements of the AREMA Manual, Volume 2, Chapter 8, Part 1, except as defined or modified herein:

a. Aggregates shall be natural aggregates complying with ASTM C33/C33M Class 4S.

b. The Supplier shall provide evidence that concrete containing aggregate from the proposed source with cement content and alkali burden similar to the job mix, has a satisfactory service history of at least five (5) years. This evidence shall include structures requiring a Class 4S aggregate.

c. The maximum size of aggregate shall be 3/4-inch. If the coarse or fine aggregate is supplied in more than one (1) size, each size shall be stored separately.

d. Washed aggregate shall be allowed to drain, in stockpiles, before use. All aggregates shall be free from ice when used.

e. In addition to the requirements of ASTM C33/C33M, the following tests shall be conducted by an Independent Testing Laboratory.

1) Petrographic examination to ASTM C295/C295M. This shall be conducted on each new source.

2) Evaluation of potential alkali reactivity shall be made according to:
a) ASTM C289 – Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

b) ASTM C227 - Aggregate Combinations (Mortar Bar Test). The alkali content, expressed as sodium oxide plus 0.658 potassium oxide shall be less than 0.6 percent by weight. The mortar bars for testing shall be made with an aggregate/cement ratio by weight of 2.25 to 1. This test may need to extend over a period of six (6) months, and should, therefore, begin early in the Contract period.

3) Evaluation of potential alkali carbonate reactivity. Aggregates containing carbonate shall be tested in accordance with ASTM C586 and ASTM C1105.

3. Mixing Water: Water shall be potable and free from harmful amounts of oils, acids, alkalis, salts, organic materials, or other substances that may be deleterious to concrete or steel. Mixing water, including that portion of the mixing water contributed in the form of free moisture on aggregates, shall have a chloride ion content of less than 100 parts per million. When required, test mixing water in accordance with AASHTO T 26.

4. Admixtures, if used:
   a. Air-Entraining Admixtures: Provide admixtures conforming to the requirements of ASTM C260/C260M.
   b. Accelerating, Retarding, and Water-Reducing Agents: Provide agents conforming to the requirements of ASTM C494/C494M.
   c. Other Pozzolanic Admixtures: Provide admixtures conforming to the requirements of ASTM C618.
   d. Do not use admixtures containing chlorides, fluorides, sulphites, nitrates, or aluminum powder.

5. Prestressing Tendons:
   a. Prestressing tendons shall be pretensioned and of one of the following types:
      1) Wire for tendons in prestressed concrete in accordance with ASTM A881/A881M.
      2) Strand for tendons in prestressed concrete in accordance with ASTM A416/A416M, ASTM A886/A886M or equal.
   b. Do not use strands larger than 7/16-inch diameter.

6. Rail Fastening Shoulders:
   a. Supplier shall utilize ductile iron shoulders conforming to ASTM A536 Grade 60-40-18 or 65-45-12. Shoulders shall be marked, on non-bearing surfaces above the concrete level, with the part number, Supplier's identification and pattern number.
      1) Shoulders shall be free from burned-on sand, cracks, cavities, injurious blow holes and other defects. Fins shall be removed from the vertical faces of the head of each shoulder. Fins across the top of the head shall not exceed 1/32-inch and below the head, fins shall not exceed 1/16-inch. At gates, there shall be no
cavity in the shoulder more than 1/8-inch below the general surface level.

2) Go and No-Go inspection gages shall be used to check that tolerances conform. A sampling plan for Acceptable Quality Levels of 1 percent for major dimensions and 4 percent for minor dimensions shall be used (see ASTM E122). The Supplier shall decide which are major and minor dimensions. These shall be indicated on the shop drawings.

b. Shoulders shall be free of mud, oil, loose rust, and other contamination when cast into ties. Shoulders shall be rigidly secured in the forms during casting and not move within the concrete when the securing device is released. Location within the ties shall comply with the Contract Drawings.

1) The shoulder shall not be directly anchored to the pretensioned steel. The shoulder shall not come in contact with pretensioned steel.

7. Embedded Anchor Inserts:

a. Anchor inserts shall conform to ASTM F3125 and have a Class 2B thread fit.

b. As part of the insert, there shall be a feature to prevent rotation of the insert after the concrete has reached its design strength. The anchor insert shall have a minimum length of 4-inches and a maximum length of 5-inches and shall have a minimum 3-inch engaging threaded length.

c. In the installed position, the top of the anchor insert shall provide a flat surface parallel to the rail base with a minimum of 1/8-inch bearing width surrounding the anchor bolt hole.

d. Inserts shall be furnished with an installed plug of metal or plastic material to preclude the entrapment of moisture, concrete, or other foreign materials. Removal shall be by using a socket or other common device. Plugs shall be capable of reinsertion, and if reinserted, shall still exclude concrete and other materials from entry.

e. Inserts shall be coated with a uniform epoxy resin insulating coating on exterior surfaces.

1) Coating material shall be 100 percent dry powder epoxy resin such as Scotch Kote Brand Protective Resin No. 203, manufactured by the Minnesota Mining and Manufacturing Company, Corvel Epoxy ECB-1363A, manufactured by the Polymer Corporation, or approved equivalent.

2) The coating application shall be in accordance with the coating Supplier’s recommendations, as specified herein, or an approved equivalent.

3) Before coating, the insert shall be degreased and cleaned to white metal in accordance with SSPC SP5.

4) The epoxy coating shall not be thinner than 10 mils or thicker than 20 mils. Epoxy coating having runs, sags, or chips will not be accepted. Thickness shall be tested by a magnetic mil gauge at not less than two areas of the insert.
5) When tested in accordance with ASTM D2440, epoxy coatings shall have a hardness of not less than 85 or more than 80 Shore D.

6) The coated insert shall be tested for pinholes and breaks in a weak electrolytic solution. A 100 volt DC electrical current shall be applied between the electrolyte and the insert; the coating will be acceptable if the circuit is not closed when the insert is immersed in the electrolytic solution. The above tests shall be performed by the epoxy coating applicator. The frequency of testing shall be in accordance with a sequential statistical quality control plan developed by the epoxy coating applicator. The plan shall ensure that the average defective rate shall not exceed 2 percent and that the maximum defective rate shall not exceed 5 percent. These defect rates shall be demonstrated at a 90 percent degree of confidence.

8. Rail Fastening Components:
   a. For standard and restraining rail concrete ties the rail fastening system shall be Pandrol FASTCLIP, or approved equal.
   b. Rail Fastening Spring Clips:
      1) Rail clips shall not be dependent on elastomeric components in torsion.
      2) One (1) identical clip design shall be used on the field and gauge side of the rail at the rail seat.
   c. Insulators between fastening shoulder and rails:
      1) Volume Resistivity: 1012 ohm-cm, minimum. Measure in accordance with ASTM D257.
      2) Water Absorption at Saturation: 3 percent, maximum. Measure in accordance with ASTM D570.
      3) Dry Shear Strength: 6500 pounds per square inch, minimum. Measure in accordance with ASTM D732.
      4) Deformation Under Load: 5 percent, maximum. Measure at 2000 pounds per square inch and 122 degrees Fahrenheit in accordance with ASTM D621.
      5) Heat Aging: Age for 10 days at 158 degrees Fahrenheit using ASTM D573 as a guide. Compare properties before and after aging at 158 degrees Fahrenheit. The tensile strength shall not decrease more than 10 percent. The Rockwell Hardness shall not change more than five (5) points. There shall be no warping, cracking, discoloration, or exudation of plasticizer.
      6) Weatherometer Test: After 1,000 hours with cycled water spray, the yield stress shall be a minimum of 8,000 pounds per square inch and the tensile strength shall be a minimum of 6,000 pounds per square inch.
   d. Rail Seat Pads:
      1) Rail seat pads shall conform to AREMA Manual Volume 1, Chapter 30.
2) Rail seat pads shall be manufactured from natural rubber or thermoplastics.

PART 3 - EXECUTION

3.01 CONCRETE DESIGN MIX

A. Trial mixtures using aggregates, water, cement, and admixtures proposed for the manufacture of the concrete ties shall be made using at least three different water-cement ratios, which will produce a range of strengths. For each water-cement ratio, at least three (3) specimens for each day of production shall be made, cured, and tested as specified herein. Each batch of concrete shall be mixed separately in a pan mixer.

B. Design compressive strength at the time proposed for transfer of prestress forces to the concrete shall be no less than 4,500 pounds per square inch, or higher if so required by the tie design or manufacturing method. Design compressive strength at 28 days shall be not less than 7,000 pounds per square inch. Design flexural strength at 28 days shall be not less than 750 pounds per square inch.

C. Aggregates and cement shall be measured by weight. The weight of aggregate shall be based on the saturated surface dry condition corrected for free moisture. Water shall be measured by weight or volume and admixtures shall be measured by volume, unless otherwise directed by the admixture Supplier.

D. Mix proportions shall be developed using the method of ACI 301, Section 3.9.

E. Restriction on design mix proportions:
   1. The cement content shall be not less than 800 pounds per cubic yard.
   2. The water-cement ratio shall not exceed 0.40 by weight. Water content shall be kept to the minimum consistent with strength requirements and placement needs.
   3. Air content in the plastic concrete shall ensure a minimum 3.5 percent air entrainment in the hardened concrete.

F. The proportions of aggregate to cement shall be such to produce a mixture that will work readily into corners and angles of the form and around the prestressing elements with the assistance of specified vibration, but without permitting the materials to segregate or excess of free water to collect on the surface.

G. The strength tests shall be made at:
   1. The age at which transfer of prestress forces shall be made, and
   2. 28 days, a curve shall be developed for each design mix showing the relationship between water-cement ratio and compressive strength.

H. Acceptance of trial mix: The maximum permissible water-cement ratio for the concrete mix to be used shall be that shown by the water-cement ratio versus strength curve to produce average strengths of 110 percent of those specified herein.

3.02 STRENGTH TESTS OF CONCRETE

A. Compressive and Flexural Strength tests shall be made to check the adequacy of the mix proportions and as a basis for acceptance. Samples for compressive test specimens shall be secured in accordance with ASTM C172/C172M. Samples for flexural tests specimens shall be secured and specimens shall be made and laboratory cured in
accordance with ASTM C31/C31M. Specimens made to check the adequacy of curing and protection of concrete shall be cured entirely under production conditions.

1. Compressive Strength tests shall be made on 6-inch by 12-inch cylinders in accordance with ASTM C39/C39M. For each day of production at least six (6) cylinders shall be prepared two (2) for 28 day testing, and two (2) for checking strength at transfer, and two (2) spares.

2. Flexural Strength tests shall be made on 6-inch by 6-inch by 20-inch beams in accordance with ASTM C78. Minimum flexural strength (modulus of rupture) at 28 days shall be 750 pounds per square inch.

3.03 FABRICATION AND FORMS

A. Design dimensions and manufacturing tolerances shall be clearly noted on the approved shop drawings. Finished ties shall not deviate from any indicated dimension by more than the manufacturing tolerance associated with that dimension.

B. Method of Production: Monoblock ties shall be manufactured by the long line process.

1. Forms shall be rigid and shall be constructed of material that will result in finished ties conforming to the shape, lines, dimensions and tolerances called for on the approved shop drawings.

2. Forms shall be constructed to permit movement of the tie without damage during release of the prestressing force.

3. Forms shall provide proper marking with indented or raised letters or numerals to identify the Owner, Supplier, day and year of manufacture, and other information, as indicated in the Contract Documents.

3.04 PLACEMENT OF PRESTRESSING STEEL

A. Prestressing force in each of the strands shall be 16,750 pounds plus or minus 500 pounds.

B. The load shall be applied in two (2) increments. An initial load of approximately 1000 pounds shall be applied to the individual strands to straighten them, eliminate slack, and provide a starting or reference point for measuring elongation.

C. Prestressing force shall be determined by one (1) measuring strand elongation and two (2) by either checking jack pressure on a calibrated gauge or by the use of a calibrated dynamometer. The cause of discrepancy that exceeds 5 percent shall be ascertained and corrected. Elongation requirements shall be taken from average load elongation curves for the steel used.

D. Strands shall be stretched either individually or simultaneously. If strands are stretched simultaneously, provision for taking up slack and equalizing stress shall be made individually as required to induce approximately equal stress in each strand.

E. Transfer of force from bulkheads of the pretensioning bed to the concrete shall be accomplished by gradual and simultaneous detensioning of all strands. Exposed strands shall be cut near the tie end. The projection of strands beyond the ends of the ties shall be no more than 1/4-inch.

3.05 MIXING, PLACING, AND CURING OF CONCRETE

A. Preparation for Placing Concrete:

1. Prior to the placing of concrete, equipment for mixing the concrete shall be clean, debris shall be removed from spaces to be occupied by the concrete, the forms
shall be thoroughly coated with a bond-breaker, and the reinforcement shall be thoroughly cleaned of deleterious coatings. The iron shoulder and prestressing wire shall not be contaminated with bond-breaker or other substance that would interfere with bond development. The forms shall be inspected for alignment and tightness of joints and dimensional accuracy of the position of bulkheads, prestressing steel, and inserts shall be verified.

2. Proportioning of Component Materials
   a. Fine and coarse aggregates and cement shall be measured by weight. Weights of aggregates shall be based on a saturated surface dry condition corrected for free moisture.
   b. Water and liquid admixtures may be measured by either weight or volume.

3. The accuracy of measurement of the various components of concrete shall be within the following limits:
   a. Cement: 1 percent
   b. Water: 1 percent
   c. Fine aggregate: 2 percent
   d. Coarse aggregate: 2 percent
   e. Cumulative aggregate: 2 percent
   f. Admixtures: 1 percent

B. Mixing of Concrete:
   1. Mixing equipment shall be capable of combining specified materials within the time specified by the equipment Supplier into a thoroughly mixed and homogeneous mass, and discharging the mixture without segregation.
   2. Concrete shall be mixed until there is a uniform distribution of the materials and shall be discharged completely before the mixer is recharged.
   3. Optimum mixing time shall be established by the equipment Supplier's recommendations. Generally, minimum mixing time shall be one (1) minute for batches of one (1) cubic yard or less. This mixing time shall be increased by at least 15 seconds for each cubic yard, or fraction thereof, of capacity more than one (1) cubic yard. Mixing time shall not exceed three (3) times the specified time.

C. Conveying:
   1. Concrete shall be conveyed from the mixer to the place of final deposit in the shortest possible time by methods that will prevent segregation or loss of materials.
   2. Equipment for chuting, pumping, and pneumatic conveying of concrete shall be of such size and design as to ensure flow of concrete at the delivery location without segregation of materials.

D. Depositing:
   1. Concrete shall be deposited as nearly as practical in its final position to avoid segregation due to rehandling or flowing. No concrete that has partially hardened or has been contaminated by foreign materials shall be used.
2. Concrete shall not be placed when the ambient air temperature of the casting room is below 40 degrees Fahrenheit. Concrete shall have a minimum temperature of 50 degrees Fahrenheit, and a maximum temperature of 90 degrees Fahrenheit. When concrete is placed at an ambient temperature of 90 degrees Fahrenheit or greater, the recommendations of ACI 305 shall be followed to prevent rapid drying and other detrimental effects of elevated temperature on fresh concrete.

E. Consolidating:
1. Concrete shall be thoroughly consolidated by vibration during placement, and shall be thoroughly worked around the prestressing elements and embedded fixtures and into corners of the forms. Consolidation at the ends of ties is paramount to comply with the void tolerance specified herein.
2. External form vibration supplemented, if necessary, by internal vibration shall be used to obtain uniform mix, and shall be sufficient to yield concrete with a density not less than 148 pounds per cubic foot.
3. Care shall be taken to assure that forms are not damaged during consolidation.

F. Surface Finishing-Bottom of Tie:
1. The bottom surface of the tie shall have a rough screeded or broom finish. Two (2) ties, which show the required bottom surface condition, shall be set aside from an early batch for acceptance.

G. Testing Fresh Concrete:
1. The first batch on any bed shall be tested and if this requires no adjustment to the mix, a further test shall be made after approximately 25 cubic yards has been poured. If the first batch requires adjustment to the mix each subsequent batch shall be tested until no further adjustment is necessary and then a further batch shall be tested after approximately 25 cubic yards has been poured.
2. Slump: When measured in accordance with ASTM C143/C143M, the slump shall not exceed 2-inches when concrete is placed in the forms.
3. Air Content: When measured in accordance with ASTM C231/C231M, the range of air content in the plastic concrete shall ensure a minimum 3.5 percent air void content in the hardened concrete.
4. Temperature: The temperature of freshly mixed concrete shall not exceed 90 degrees Fahrenheit.

H. Curing:
1. Immediately after placing and consolidating the concrete, the exposed surface shall be covered with impermeable sheeting.
2. Concrete shall not be placed in forms whose temperature is less than 40 degrees Fahrenheit and the concrete temperature shall not be allowed to fall below 50 degrees Fahrenheit between casting and transfer of prestress.
3. The rate of temperature rise in the concrete shall not exceed 35 degrees Fahrenheit per hour and the maximum concrete temperature shall not exceed 175 degrees Fahrenheit. Transfer of prestress shall not be carried out at a concrete temperature above 135 degrees Fahrenheit. The heating method used shall be such that ties in a bed are at a similar temperature.
4. Curing shall be done in accordance with established procedures to produce concrete strength as specified.
I. Detensioning: Stress transfer shall be performed in a controlled manner with hydraulic jacks. The forms shall be free to move and the stress in wires shall be transferred at the same time and same rate. No wire shall be cut until it is completely detensioned.

3.06 REMOVAL OF TIES FROM FORMS AND FINISHING

A. Ties shall be removed from forms in a manner such as to avoid damage.

B. Surface Finishing:

1. Formed surfaces of the finished tie shall have a uniformly dense surface. The surface of the rail seat shall have a smooth finish and be free from honeycomb, surface irregularities, and air holes more than 1/8-inch diameter. Other surfaces shall have a smooth finish that may contain honeycomb not to exceed 2 percent of the surface and a maximum void diameter of 1/4-inch.

2. Two (2) ties, which show the required surface finish, and two (2) ties, which show the maximum allowable rail seat defects, shall be set aside as comparison standards for acceptance of ties. These four (4) ties shall be in addition to those for bottom finish comparison.

C. Inspection and Repair of Surface Defects:

1. Every tie produced shall be visually inspected by the Supplier.

2. The surface of the rail seat shall have a smooth, formed finish not inferior to the comparison standards. No rubbing, brushing or other treatment shall be used on the rail seat.

3. Surface conditioning with a mixture of three parts sand and one part cement mixed with one part latex cement mix and one part water shall be undertaken on surfaces containing air pockets. The maximum size of any one pocket shall not exceed 3/8-inch diameter by 1/4-inch deep.

4. Ties with voids not deeper than 3/4-inch around not more than two end wires shall be repaired with a silicone rubber sealant. Ties with voids beyond this limit will be rejected.

5. Corner breakage less than 1/2-inch deep and 1-1/2-inches along the end faces need not be repaired providing reinforcing wire is not exposed. If the wire is exposed the breakage shall be repaired.

6. Corner breakage from 1/2-inch to 1-1/2-inches in depth shall be repaired. Corner breakage more than that will be rejected.

7. Prestressing wires protruding more than 1/4-inch beyond the concrete surface of the end of the tie shall be cut back. Sharp ends, which would be hazardous in handling, shall be smoothed or cut back.

3.07 QUALITY CONTROL

A. Concrete Tie Tests:

1. Prior to approval of the concrete tie design, the following tests shall be performed. The tie samples submitted will be subjected to testing for compliance as specified herein.

2. From a lot of not less than five (5) ties produced, three (3) ties shall be selected at random for testing. If required for design testing of the fastening system, the Supplier shall also furnish a section of a tie or a concrete block with rail seat and fastening system identical to the concrete ties furnished for testing. A separate test series shall be conducted for each cross tie supplied.
3. Each of the three (3) ties and, if required, the tie block submitted for testing shall be carefully measured and examined to determine compliance with the requirements as specified herein. Upon satisfactory completion of the examination, two (2) ties, designated as Tie No. 1 and Tie No. 2, shall be subjected to the specified performance tests. The remaining tie, which will be designated as Tie No. 3, will be retained for further testing and as a control for dimensional tolerances and surface appearance of ties subsequently produced.

a. Sequence of Design Tests (Tie No. 1):

1) The sequence of design performance tests using Tie No. 1 shall be as follows:
   a) Rail seat positive bending moment test shall be performed on the two (2) rail seats designated "A" and "B".
   b) Tie Center Negative Bending Moment Test.
   c) Bond Development, Tendon Anchorage, and Ultimate Load Test shall be performed on rail seat "A".

2) Rail Seat Positive Bending Moment Test:
   a) Test procedure and acceptance criteria are shown in Figure 1.
   b) Summary of Test: With the tie supported and loaded as shown in Figure 1, apply load at a uniform rate and in such a manner as to avoid shock until the stated load is obtained. This load shall be held for not less than three (3) minutes, during this time an inspection shall be made to determine if structural cracking has occurred. A five-power magnifying glass may be used to locate cracks. If structural cracking has not occurred, the requirements of this test will have been met.
   c) This test shall be performed on both rail seats on Tie No. 1.

3) Tie Center Negative Bending Moment Test:
   a) Test procedure and acceptance criteria are shown in Figure 2.
   b) Summary of Test: With the tie supported and loaded as shown in Figure 2, apply load at a uniform rate and in such a manner as to avoid shock until the stated load is obtained. This load shall be held for not less than three (3) minutes, during this time an inspection shall be made to determine if structural cracking has occurred. A five-power magnifying glass may be used to locate cracks. If structural cracking has not occurred, the requirements of this test will have been met.

4) Bond Development and Ultimate Load Test:
   a) Test procedure and acceptance criteria are shown in Figure 3.
   b) Summary of Test: With the tie supported and loaded as shown in Figure 3, apply load at a uniform rate and in
such a manner to avoid shock and increased until the stated load is obtained. The load shall be held for not less than three (3) minutes. If there is no more than 0.001-inch strand slippage determined by an extensometer reading to 0.0001-inch, the requirements of this test will have been met. The measurements shall be made on the outermost tendons of the lower layer. The load shall be increased until ultimate failure occurs. The ultimate failure load so obtained shall exceed 47,800 pounds.

b. Sequence of Design Tests (Tie No. 2):

1) The sequence of design performance tests using Tie No. 2 shall be as follows:

a) Rail Fastening Insert Shoulder Pullout and Torque Test shall be performed on all inserts and shoulders.

b) Rail Fastening Uplift Test shall be performed on one rail seat.

c) Electrical Resistance and Impedance Test.

2) Rail Fastening Shoulder and Insert Pullout and Torque Tests:

a) Test procedure and acceptance criteria are shown in Figure 4.

b) Summary of Test: The following test shall be performed on each shoulder and insert as indicated in Figure 4 to determine the ability of shoulder and inserts to resist tension and rotation. The stated axial load shall be applied to each shoulder and insert separately and shall be held for not less than three (3) minutes. Each insert shall then be subjected to the stated torque test. The embedded shoulders and inserts shall not move and the concrete shall not crack, as observed by visual inspection. Separation of laitance surrounding the insert will not be cause for rejection.

3) Rail Fastening Uplift Test:

a) Test procedure and acceptance criteria are shown in Figure 5.

b) Summary of Test: A 19-inch section of 115 RE rail shall be secured to one rail seat using a complete rail fastening system including pads, clips, and associated hardware, as recommended by the Supplier of the rail fastening system. In accordance with the loading diagram and method described in Figure 5, an incremental load shall be applied to the tie. The maximum, as determined fastener uplift load, shall then be applied. The inserts shall not pull out or loosen in the concrete and no component of the fastening system shall fracture nor shall the rail be released.
4) Electrical Resistance and Impedance Test (Wet or Dry):
   a) Test procedure and acceptance criteria are shown in Figure 6.
   b) Summary of Test: Secure two short pieces of 115 RE rail to the tie using complete concrete tie fastenings. The rail pieces shall be no longer than the width of the tie. Clean contact points on each rail and attach cables. Clean a contact point on a pretensioned tendon near the middle of one end of the tie and attach a cable (hereinafter designated as a ground). Tests, test methods, procedures, and acceptance criteria shall be in accordance with those shown on Figure 6. The minimum resistance for 500 volts DC shall be 10 megohms when dry and 0.4 megohm when wet. The minimum impedance for frequencies between 20 hertz and 12 kilohertz with 50 volts AC applied shall be 10,000 ohms when wet.
   c) Dimensional Tolerances and Surface Appearance of Ties.

B. Fastening Systems Tests:

1. Fasteners shall be subjected to the acceptance tests as specified herein. Failure of fastening system to pass tests will be cause for rejection. Certified laboratory test reports shall be submitted in sufficient detail to the Resident Engineer.

2. Acceptance of design testing of the fastening system consists of testing of components cast into the concrete tie in addition to tests conducted on the external components.

3. Acceptance design tests for rail seat pad shall consist of the following:
   a. Specimens: Perform the following tests on each of two (2) specimens. The specimens shall be manufactured and cured in the same manner as the final product. Use a separate pair of specimens for each test, except the accelerated aging tests. Prior to testing, condition specimens for at least 7 days at 74 degrees Fahrenheit and 50 percent relative humidity. Failure of either of the two (2) specimens to meet requirements will be cause for rejection.
   b. Hardness: Measure the hardness in accordance with ASTM D2240. The reading on each pad shall be between 50 and 80 durometer, Shore A. Average the two (2) readings and record the average for reference in production testing.
   c. Tensile Strength, measured by ASTM D412: shall be minimum of 1,500 pounds per square inch.
   d. Ultimate Elongation, measured by ASTM D412: shall be minimum of 250 percent.
   e. High Temperature Compression Set: Using Method B of ASTM D395 with a Type 2 specimen, test for 22 hours at 212 degrees Fahrenheit. The compression set shall not exceed 25 percent.
   f. Compression Set at Minus 65 degrees Fahrenheit: Using ASTM D1229, test for 22 hours at minus 65 degrees Fahrenheit. The specimen
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Thickness shall be 6.0 plus or minus 0.2-millimeter. The compression set at 30 minutes after release (t30 reading) shall not exceed 40 percent.

g. Accelerated Aging: Using ASTM D573, age the elastomer for 48 hours at 212 degrees Fahrenheit. Measure and record the change in hardness, tensile strength, and ultimate elongation. The tensile strength shall not decrease more than 15 percent. The ultimate elongation after aging shall be at least 200 percent and shall be at least 60 percent of the durometer A scale. The durometer A scale shall not vary more than 10 points from pre-aging values.

h. Resistance to Ozone Cracking: Prepare the specimens in accordance with procedure A of ASTM D1149. Test the specimens in accordance with ASTM D1149 at a temperature of 104 degrees Fahrenheit and an ozone concentration of 50 parts per hundred million. The elastomer shall not exhibit cracking when examined in accordance with ASTM D1149 at the end of a 100 hour exposure.

i. Oil Absorption: Using ASTM D471, conduct one test with ASTM No. 3 oil at 212 degrees Fahrenheit for 70 hours and conduct another test using a different sample with ASTM No. 1 oil at 212 degrees Fahrenheit for 70 hours to determine the volume change of the elastomer. For No. 1 oil, the volume change shall not exceed minus 10 or plus 20 percent. For No. 3 oil, the volume change shall not exceed 100 percent.

j. Volume Resistivity: Apply 100 volts DC for three (3) minutes. The volume resistivity, measured in accordance with ASTM D257, shall be at least 1 x 1012 ohm-cm.

k. Water Absorption: Using ASTM D471, test 70 hours at 212 degrees Fahrenheit in distilled water. The volume change shall not exceed plus 35 or minus zero percent.

C. Rail Seat Pads Tests:

1. Batch Control: A batch is defined as the rubber mixed, processed and cured together, not exceeding one (1) day's production. Keep the pads segregated by batch. Perform the following tests on two (2) samples chosen from each batch at random. Use two (2) different specimens for each test. If either of the two (2) samples fails a test, the entire batch shall be either rejected or subjected to the test that the sample failed. Prior to testing, condition specimens for at least 7 days at 74 degrees Fahrenheit and 50 percent relative humidity.

2. Hardness: When measured in accordance with ASTM D2240, the hardness shall be within plus or minus 5 durometer, Shore A, of the average recorded herein.

3. Tensile strength, ultimate elongation, high temperature compression set, volume resistivity and water absorption: Test as specified herein.

D. Fastening Assembly Tests:

1. The sequence of design tests for the fastening assembly, if required to be conducted on the tie block shall be as follows:

   a. Rail Fastening Repeated Load Test.

   b. Rail Fastening Longitudinal Restraint Test.

   c. Rail Fastening Lateral Restraint Test.
2. Rail Fastening Repeated Load Test:
   a. Test procedure and acceptance criteria are shown in Figure 7.
   b. Summary of Test: A 19-inch section of 115 RE rail, from which loose mill scale has been removed, shall be secured to the rail seat using a complete rail fastening assembly. Three million cycles of loading shall be applied in accordance with the loading diagram in Figure 7, alternating downward and upward loads at an angle of 20 degrees to the vertical axis of the rail. Rupture failure of any component of the fastening system shall constitute failure of the test.

3. Rail Fastening Longitudinal Restraint Test:
   a. Test procedure and acceptance criteria are shown in Figure 8.
   b. Summary of Test: After successful completion of the Rail Fastening Repeated Load Test specified above and without disturbing the rail fastening assembly in any manner, the tie and fastening shall be subjected to a longitudinal restraint test. An increasing longitudinal load shall be applied in 400 pound increments as indicated in Figure 8. The load shall be increased until the stated load is reached. The stated load shall be held for not less than fifteen (15) minutes. The fastenings shall meet the requirements of this test in either direction of loading. The fastenings will have successfully passed this test if the rail movement is less than 0.125-inch.

4. Rail Fastening Lateral Restraint Test:
   a. Test procedure and acceptance criteria are shown in Figure 9.
   b. Summary of Test: A 19-inch section of 115 RE rail shall be secured to the rail seat using a complete fastening assembly. The entire assembly shall be supported and loaded as indicated in Figure 9. Both restrained and unrestrained lateral load tests shall be performed as described in Figure 9. Inability of the fastening to carry a 20 kip load with 1/8-inch or less of rail translation shall constitute failure of the restrained lateral load test. Rail rotation, gauge widening less rail translation, greater than 1/4-inch under an applied load of 10 kips shall constitute failure of the unrestrained lateral load test. Complete failure of any component of the tie or fastening is cause for rejection.

E. Daily Production Control Tests:

1. Acceptance Tests:
   a. At the start of production, a minimum of six (6) rail seat positive, six (6) tie center negative, and six (6) shoulder pull-out tests shall be undertaken by the Supplier on randomly selected ties to establish compliance as specified herein. After the acceptance test load results are checked, additional loading shall be applied to the ties to produce the first crack greater than 1-inch in vertical length and these loads and crack lengths recorded.

2. Routine Production Testing:
   a. Routine acceptance testing shall be carried out on all beds cast. One (1) tie selected from every 200 ties or fraction thereof from one (1) form, selected at random from each bed cast, shall be load tested as follows:
      1) Rail Seat Positive Bending Moment Test - Figure 1, at both seats.
2) If structural cracking occurs in the tests, two (2) additional ties from the same lot shall be subjected to the same test and acceptance of the lot shall be based on the following conditions:
   a) If both retest ties meet the test requirements, the lot will be accepted;
   b) If either of the retest ties fails to meet the test requirements, the remaining ties shall be tested in accordance with a statistical sampling plan.

b. One (1) tie selected at random from every 200 ties or fraction thereof produced each day shall be subjected to testing the distance from the center of track to the center of rail seats by use of a steel template, the rail seat configuration and shoulder insert location shall be verified.

c. One (1) tie per 1,000 cast shall be selected at random from those ties previously subjected to the Rail Seat Positive Bending Moment Test one (1) of every five (5) of such ties shall additionally be tested for Bond Development.
   1) If strand slippage does not exceed 0.001-inch, the requirements of this test will have been met.
   2) If strand slippage exceeds 0.001-inch, three (3) additional ties shall be tested. If any of the three (3) ties does not meet the requirements of the test, the remaining ties in the lot shall be tested in accordance with a statistical sampling plan.

3.08 INSTALLATION
A. Concrete cross ties shall be installed in accordance with track construction requirements as stated elsewhere in the Contract Documents.

3.09 FIGURES
A. Figure 1 - Rail Seat Positive Bending Moment Test
B. Figure 2 – Tie Center Negative Bending Moment Test
C. Figure 3 – Bond Development and Ultimate Load Test
D. Figure 4 – Rail Fastening Shoulder & Insert Pullout & Torque Tests
E. Figure 5 – Rail Fastening Uplift Test
F. Figure 6 – Electrical Resistance and Impedance Test
G. Figure 7 – Rail Fastening Repeated Load Test
H. Figure 8 – Rail Fastening Longitudinal Restraint Test
I. Figure 9 – Rail Fastening Lateral Restraint Test
3.07.C RAIL SEAT POSITIVE BENDING MOMENT TEST

3.07.C.1 The concrete tie shall be supported in a hydraulic testing machine as shown below with loading points so arranged that the load is applied at right angles to the base of the tie midway between the supporting pads. (The "Y" dimension represents the distance from bottom of tie to bottom row of prestressing wires.)

3.07.C.2 A test load of 28.1 kips shall be applied at a rate not exceeding 5 kips per minute. The load shall be held for 3 minutes, during which time the inspection shall be made to determine if structural cracking has occurred. Both sides of the tie shall be inspected for cracks. Both rail seats of the tie shall be tested.

3.07.C.3 ACCEPTANCE CRITERIA

If structural cracking has not occurred when viewed under 5 power magnification, the requirement of the test will have been met. The illumination at the surface during inspection shall be not less than 125 foot candles.
3.07.D TIE CENTER NEGATIVE BENDING MOMENT TEST

3.07.D.1 The concrete tie shall be supported in a hydraulic testing machine as shown below with loading points so arranged that the load is applied at right angles to the base of the tie midway between the supporting pads.

\[ P = \frac{3}{2}m \] - Test load:
- 8'-3" TIE = 8.9 kips
- 8'-6" TIE = 8.0 kips

\[ M = \text{Negative moment rating at the center of tie:} \]
- 8'-3" TIE = 120 in-kips
- 8'-6" TIE = 100 in-kips

3.07.D.2 A test load of 8.0 or 8.9 kips (depending on tie length) shall be applied at a rate not exceeding 5 kips per minute. The load shall be held for 3 minutes, during which time the inspection shall be made to determine if structural cracking has occurred. Both sides of the tie shall be inspected.

3.07.D.3 ACCEPTANCE CRITERIA

If structural cracking has not occurred when viewed under 5 power magnification, the requirement of the test will have been met. The illumination at the surface during inspection shall be not less than 125 foot candles.
3.07.E BOND DEVELOPMENT AND ULTIMATE LOAD TEST

3.07.E.1 THE CONCRETE TIE SHALL BE SUPPORTED IN A HYDRAULIC TESTING MACHINE AS SHOWN BELOW WITH LOADING POINTS SO ARRANGED THAT THE LOAD IS APPLIED AT RIGHT ANGLES TO THE BASE OF THE TIE MIDWAY BETWEEN THE SUPPORTING PADS. (THE "Y" DIMENSION REPRESENTS THE DISTANCE FROM BOTTOM OF TIE TO BOTTOM ROW OF PRESTRESSING WIRES.)

2 1/4"

2 1/4"

8'-3"X8'-6"

CONCRETE TIE LENGTHS
TIE NO. 1

30" TO CENTERLINE OF TIE

8'-3" TE = 10 1/2"

8'-8" TE = 21"

2' = 0.67X - 2 1/4"

0.33X x 6'-3" TE = 6 1/2"

0.33X x 8'-6" TE = 13"

0.67X x 8'-3" TE = 14"

0.67X x 8'-6" TE = 17"

307.E.2 BOND DEVELOPMENT TEST

A TEST LOAD OF 42.2 KIPS SHALL BE APPLIED AT A RATE NOT EXCEEDING 5 KIPS PER MINUTE. THE LOAD SHALL BE HELD FOR 3 MINUTES DURING WHICH TIME THE TWO INSPECTION MEASUREMENTS SHALL BE MADE TO DETERMINE IF STRAND SLIPPAGE OCCURS. MEASUREMENTS SHALL BE MADE ON THE OUTERMOST TENDONS OF THE LOWER LAYER USING AN EXTENSOMETER READING TO 0.0001 OF AN INCH.

3.07.E.3 ACCEPTANCE CRITERIA

IF THERE IS NO MORE THAN 0.00001 INCH TENDON SLIPPAGE THE REQUIREMENT OF THE TEST WILL HAVE BEEN MET.

3.07.E.4 ULTIMATE LOAD TEST

CONTINUING FROM THE ABOVE TEST THE LOAD SHALL BE INCREASED UNTIL ULTIMATE FAILURE OCCURS AND THE MAXIMUM LOAD OBTAINED AT ULTIMATE FAILURE SHALL BE RECORDED.

3.07.E.5 ACCEPTANCE CRITERIA

THE MAXIMUM LOAD AT ULTIMATE FAILURE SHALL EXCEED 47.8 KIPS.
3.07.G RAIL FASTENING SHOULDER & INSERT PULLOUT & TORQUE TESTS

3.07.G.1 The concrete tie shall be supported on a hydraulic testing machine as shown below with loading points so arranged that the load is applied at right angles to the rail seat of the tie. The test shall be applied to each angle insert and shoulder separately.

3.07.G.2 PULL OUT TEST

A vertical test load of 12 kips shall be applied to each shoulder and insert at a rate not exceeding 5 kips per minute. The load shall be held for 3 minutes, during which time the inspection shall be made to determine if the shoulder or insert has moved or deformed.

3.07.G.3 TORQUE TEST

A torque of 250 foot pounds shall be applied to each insert. The load shall be held for 3 minutes during which time the inspection shall be made to determine if the insert moved.

3.07.G.4 ACCEPTANCE CRITERIA

If slippage of the shoulder or insert, or any cracking of the concrete, has not occurred the requirement of the tests will have been met. Mortar cracking and separation of laitance in the vicinity of the insert will not be cause for rejection. Inability of the shoulders or inserts themselves to resist both the 12 kip vertical load and the 250 ft. lb. axial torque tests without permanent deformation shall constitute failure of the test.
3.07.H RAIL FASTENING UPLIFT TEST

3.07.H.1 AN 10 INCH LONG SECTION OF 115 RE RAIL SHALL BE SECURED TO ONE RAILSEAT USING A COMPLETE RAIL FASTENING SYSTEM INCLUDING PADS, CLIPS, AND ASSOCIATED HARDWARE, AS RECOMMENDED BY THE MANUFACTURER OF THE RAIL FASTENING SYSTEM.

THE CONCRETE TIE WITH FASTENING SHALL BE SUSPENDED IN A HYDRAULIC TESTING MACHINE AS SHOWN BELOW WITH LOADING POINTS SO ARRANGED ON THE TIE THAT THE LOAD IS APPLIED AT RIGHT ANGLES TO THE BASE OF THE TIE MIDWAY BETWEEN THE LOAD APPLICATION PADS.

3.07.H.2 AN INCREMENTAL LOAD SHALL BE APPLIED TO THE TIE TO DETERMINE THE LOAD "P" (PLUS THE UNSUPPORTED CONCRETE TIE WEIGHT AND FRAME WEIGHT) AT WHICH SEPARATION OF THE RAIL FROM THE TIE PAD OR TIE PAD FROM THE CONCRETE TIE SEAT OCCURS. THIS LOAD "P" SHALL BE RECORDED. THE LOAD SHALL THEN BE COMPLETELY RELEASED.

3.07.H.3 AN UPLIFT TEST LOAD OF THE LESSER OF EITHER 1.5P OR 10 KIPS SHALL THEN BE APPLIED.

3.07.H.4 ACCEPTANCE CRITERIA

IF THE INSERTS DO NOT PULL OUT OR LOOSEN IN THE CONCRETE AND NO COMPONENT OF THE FASTENING SYSTEM FRACTURES AND THE RAIL IS NOT RELEASED, THE REQUIREMENT OF THE TEST WILL HAVE BEEN MET.
3.07.1 ELECTRICAL RESISTANCE AND IMPEDANCE TEST

3.07.1.1 Secure two short pieces of 115 RE rail to the tie using complete concrete tie fastenings. The rail pieces shall be no longer than the width of the tie. Clean contact points on each rail and attach cables. Clean a contact point on a pretensioned tendon near the middle of one end of the tie and attach a cable (hereinafter designated as a ground).

3.07.1.2 DRY DC RESISTANCE TEST

Apply 500 volts DC from each rail to ground with an accuracy of plus or minus two percent.

3.07.1.3 ACCEPTANCE CRITERIA

The minimum resistance for 500 volts DC shall be 10 megohm (dry).

3.07.1.4 PREPARATION FOR WET ELECTRICAL TEST

The complete rail and tie fastenings assembly shall be immersed in water for a minimum of 6 hours at room temperature.

3.07.1.5 WET DC RESISTANCE TEST

Within one hour after removal from the water, without drying, test the assembly for electrical resistance. Apply 500 volts DC from each rail to ground for three minutes each. Measure the resistance from each rail to ground with an accuracy of plus or minus two percent.

3.07.1.6 WET AC IMPEDANCE TEST

Immediately after removal from the water and without drying, test the assembly for electrical impedance. Apply a potential of 50 volts AC from each rail to ground for three minutes at frequencies from 20 hertz to 12 kilohertz in increments of 20 hertz up to 100 hertz, then in increments of 200 hertz from 200 hertz to 1,000 hertz and in increments of 2 kilohertz from 2 kilohertz up to 12 kilohertz. The impedance after three minutes shall be measured with an accuracy of plus or minus two percent and recorded for each frequency.

3.07.1.7 ACCEPTANCE CRITERIA

The minimum for 500 volts DC shall be 0.4 megohm (wet). The minimum impedance for any frequency between 20 hertz and 12 kilohertz with 50 volts AC applied shall be 10,000 ohms.
3.08.F RAIL FASTENING REPEATED LOAD TEST

3.08.F.1 A CONCRETE TIE WITH A NEW COMPLETE FASTENING ASSEMBLY AND A 10 INCH SECTION OF NEW RAIL, WITH MILL SCALE REMOVED, SHALL BE INSTALLED AT THE RAIL SEAT.

THE CONCRETE TIE WITH FASTENING SHALL BE SUPPORTED IN A HYDRAULIC TESTING MACHINE AS SHOWN BELOW WITH UPWARD AND DOWNWARD LOADING SO ARRANGED THAT THE LOAD IS APPLIED AT AN ANGLE OF 20° TO THE VERTICAL AXIS OF THE RAIL.

3.08.F.2 A DUAL TEST LOAD OF 30° KIPS AND 0.6P SHALL BE APPLIED ALTERNATING DOWNWARD AND UPWARD RESPECTIVELY, AT A RATE NOT EXCEEDING 300 CYCLES PER MINUTE. THE RAIL SHALL BE FREE TO ROTATE UNDER THE APPLIED LOADS. ONE CYCLE SHALL CONSIST OF BOTH A DOWNWARD AND UPWARD LOAD. TEST SHALL CONSIST OF 3,000,000 CYCLES.

THIS REPEATED LOAD TEST MAY GENERATE HEAT IN ELASTOMERIC RAIL SEAT PADS. PAD TEMPERATURE SHALL NOT BE ALLOWED TO EXCEED 120° F. HEAT BUILD-UP SHALL BE CONTROLLED BY REDUCING THE RATE OF LOAD APPLICATION OR BY PROVIDING PERIODS OF REST TO ALLOW COOLING OF THE PAD TO TAKE PLACE.

3.08.F.3 ACCEPTANCE CRITERIA

IF RUPTURE FAILURE OF ANY COMPONENT OF THE FASTENING SYSTEM DOES NOT OCCUR, THE REQUIREMENT OF THE TEST WILL HAVE BEEN MET.

*IF SPRINGS ARE USED TO GENERATE UPWARD LOAD THE DOWNWARD LOAD SHALL BE 30 KIPS PLUS 0.6P. IF A DOUBLE ACTING HYDRAULIC RAM IS USED TO GENERATE BOTH UPWARD AND DOWNWARD LOAD, USE LOADS AS SPECIFIED.
3.08.G RAIL FASTENING LONGITUDINAL RESTRAINT TEST

3.08.G.1 SUPPORT A SUCCESSFUL CONCRETE TIE WITH FASTENING ASSEMBLY FROM TEST 3.08.F - REPEATED LOAD TEST (WITHOUT DISTURBING THE RAIL FASTENING ASSEMBLY) IN A HYDRAULIC TESTING MACHINE AS SHOWN ON THE RIGHT, WITH TWO DIAL GAGES, AND LOADING POINT SO ARRANGED THAT THE LOAD IS APPLIED LONGITUDINAL TO THE BASE AND CENTERLINE AXIS OF THE RAIL.

3.08.G.2 THE TEST LOADING SHALL BE APPLIED IN INCREMENTS OF 400 POUNDS. LONGITUDINAL RAIL DISPLACEMENT READINGS SHALL BE RECORDED AT EACH INCREMENT. RECORDED READINGS TO 0.001 INCH SHALL BE THE AVERAGE OF THE TWO GAGES.

3.08.G.3 THE TEST LOAD SHALL BE INCREASED INCREMENTALLY TO A LOAD OF 2.4 KIPS AND HELD FOR NOT LESS THAN 15 MINUTES, UNLESS RAIL MOVEMENT EXCEEDS 0.125 INCHES AT A LESSER LOADING.

3.08.G.4 ACCEPTANCE CRITERIA

IF THE RAIL MOVEMENT IS LESS THAN 0.125 INCHES DURING THIS TEST PERIOD THE REQUIREMENT OF THE TEST WILL HAVE BEEN MET. THE FASTENING ASSEMBLY SHALL MEET THE REQUIREMENTS OF THIS TEST WITH LOADING IN EITHER DIRECTION.
3.08.H RAIL FASTENING LATERAL RESTRAINT TEST

3.08.H.1 A CONCRETE TIE WITH A NEW COMPLETE FASTENING ASSEMBLY AND A 19 INCH SECTION OF NEW RAIL, WITH MILL SCALE REMOVED, SHALL BE INSTALLED AT THE RAIL SEAT.

THE CONCRETE TIE WITH FASTENING SHALL BE SUPPORTED IN A HYDRAULIC TESTING MACHINE AS SHOWN BELOW WITH THE LOADING HEAD FIXED AGAINST TRANSLATION AND ROTATION.

\[ P = 20 \text{kips} \]

- 1/2" x 1/4" FLAT WOODEN BLOCK (EXTERIOR GRADE PLYWOOD)
- DIAL GAGE FOR READING GAUGE WIDENING
- CONCRETE BE OR BLOCK
- TEST BED
- SUPPORT

3.08.H.2 RESTRANDED LATERAL LOAD TEST

A PRELOAD OF 10 KIPS SHALL BE APPLIED TO THE RAIL TO SEAT THE RAIL IN THE FASTENING. UPON RELEASE OF THE PRELOAD, A ZERO READING SHALL BE TAKEN ON THE DIAL GAGE INDICATORS THAT MEASURE RAIL TRANSLATION. LOAD SHALL BE APPLIED AT A RATE NOT TO EXCEED 5 KIPS PER MINUTE UNTIL EITHER 20 KIPS HAVE BEEN APPLIED OR THE RAIL BASE HAS TRANSLATED 1/8 INCH, WHICHEREVER OCCURS FIRST.

3.08.H.3 ACCEPTANCE CRITERIA, RESTRANDED LATERAL LOAD TEST


3.08.H.4 UNRESTRANDED LATERAL LOAD TEST

WITH ALL LOAD REMOVED FROM THE RAIL, A ROLLER NEST SHALL BE PLACED BETWEEN THE FIXED LOADING HEAD AND THE WOOD BLOCK ON THE RAIL HEAD. THE ROLLER NEST SHALL NOT OFFER RESISTANCE TO LATERAL MOVEMENT OF THE RAIL HEAD. AFTER TAKING ZERO READINGS ON THE DIAL GAGE INDICATORS, THAT MEASURE GAUGE WIDENING AND RAIL TRANSLATION, A LOAD OF 10 KIPS SHALL BE APPLIED AT A RATE NOT TO EXCEED 5 KIPS PER MINUTE.

3.08.H.5 ACCEPTANCE CRITERIA, UNRESTRANDED LATERAL LOAD TEST

RAIL ROTATION, DEFINED AS GAUGE WIDENING LESS RAIL TRANSLATION, GREATER THAN 1/4 INCH SHALL CONSTITUTE FAILURE OF THIS TEST.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes requirements for furnishing all labor, materials, and equipment for manufacturing, testing, fabricating, and delivering direct fixation fasteners as specified within the Contract Documents.

B. This Section is shall serve as a performance specification for the direction fixation fasteners.

1.02 REFERENCES
A. This Section incorporates by reference the latest revision of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   a. AREMA Manual for Railway Engineering (AREMA Manual)

2. American Institute of Steel Construction (AISC)
   a. AISC Steel Construction Manual

3. ASTM International (ASTM)
   a. ASTM A36/A36M Standard Specification for Carbon Structural Steel
   d. ASTM F3125/F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions
   e. ASTM A536 Standard Specification for Ductile Iron Castings
   f. ASTM A730 Standard Specification for Forgings, Carbon and Alloy Steel, for Railway Use
   g. ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials
   h. ASTM D395 Standard Test Methods for Rubber Property - Compression Set
   i. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension
j. ASTM D429 Standard Test Methods for Rubber Property - Adhesion to Rigid Substrates

k. ASTM D471 Standard Test Method for Rubber Property - Effect of Liquids

l. ASTM D573 Standard Test Method for Rubber - Deterioration in an Air Oven

m. ASTM D1149 Standard Test Methods for Rubber Deterioration - Cracking in an Ozone Controlled Environment

n. ASTM D1229 Standard Test Method for Rubber Property - Compression Set at Low Temperatures

o. ASTM D2240 Standard Test Method for Rubber Property - Durometer Hardness


q. ASTM E662 Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials


4. The Society for Protective Coatings (SSPC)
   a. SSPC SP 5 White Metal Blast Cleaning

1.03 SUBMITTALS

A. Technical Data: Include shop drawings for each fastener and all information including details showing dimensions, arrangement, and material description for each component in fastener assembly.

B. Product Data: Product data, catalog cuts, drawings, material specifications, and installation instructions for each component in the fastener assembly and furnished products.

C. Samples:

   1. Transmit two (2) identical samples of the direct fixation fastener.

   2. Label each sample indicating:

      a. Contract Name and Number

      b. Name of Contractor and Subcontractor

      c. Material or equipment represented

      d. Source

      e. Name of manufacturer and brand

      f. Reference specifications section and article numbers
3. Qualification Statement: Transmit documentation pertaining to fasteners conformance to the requirements as specified herein. Document shall include Contractor’s certification that furnished products meet specified requirements.

D. Certifications:
   1. Transmit rail clip Supplier’s approval of rail hold-down spring clip application on proposed direct fixation fastener as specified herein.
   2. Transmit certification of each elastomer batch used as specified herein.

E. Transmit threaded element installation data as specified herein.

F. Transmit direct Fixation Fastener Testing: Provide test results documentation as required for the Work as specified herein.

G. Submit a detailed narrative explaining the Quality Control Program and description of procedures to be utilized for the Work and a description of the organization to be used on the Contract.

1.04 QUALITY ASSURANCE

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality required by the Contract Documents.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Fasteners shall be packed and shipped in a manner that shall prevent a load on any fastener from exceeding 1,000 pounds.

B. Fasteners shall not be stored by the Contractor in a wet location or where the ambient temperature will exceed 120 degrees Fahrenheit.

C. Fasteners and assemblies shall be packaged to permit outdoor storage.

D. Fastener bodies shall be palletized and banded. Rail hold-down assemblies, shoulders, bolts, nuts, and other loose items shall be packaged by component type in secure shipping kegs, boxes, or bags. All items shall be clearly identified as to the contents.

E. Damage: Replace fasteners and assemblies damaged during packaging, shipping, storage, and handling. Special care shall be taken to protect the threaded lengths of bolts to prevent damage.

PART 2 - PRODUCTS

2.01 DIRECT FIXATION FASTENER

A. Manufacturers:
   1. Direct fixation fasteners Manufactures are required to five years of direct fixation fastener in-service performance history.

B. Fastener Description:
   1. The direct fixation fastener shall be for 115 RE rail, with spring clips in the right-hand configuration.
2. Provide, on both sides of the rail base, a positive means of preventing more than 1/8-inch total lateral movement of the rail base relative to the shoulders in case of failure or loosening of one or both spring clips.

3. The lateral rail restraint shall extend a minimum of 3/8-inch vertically, but not higher than 1-3/4-inches above the base of rail in the installed position.

4. The direct fixation fastener shall utilize a spring clip type element with non-threaded components to form the rail hold down assembly, fasteners shall utilize the Pandrol E-clip or approved equal.

5. The assembled direct fixation fasteners shall provide a canted rail seat to provide a 40 to 1 rail cant when mounted to a flat, level surface. Assembled direct fixation fasteners tapered rail seat shall be towards the centerline of the track.

6. Two anchorage insert assemblies per fastener, for securing the direct fastener to the plinth concrete.

7. Direct fixation fasteners shall be composed of as few components as is economically and technically practicable for ease of assembly, disassembly, and maintenance, and shall be designed to permit installation and replacement of the entire assembly or its components by one worker using standard conventional hand tools.

8. Direct fixation fastener shall be designed to dampen lateral and vertical dynamic forces transferred to anchor bolts.

9. In its installed position, the underside of the fastener shall be a flat plane. Base protrusions into the plinth concrete will not be allowed.

10. Bonding of the direct fixation fastener to the plinth concrete shall not be permitted.

11. Fastener plates shall have full bearing on the elastomer in positions of lateral adjustment and have a means of preventing displacement of the elastomer.

12. Stability of the fastener shall not be dependent solely upon the strength of bonding of the elastomer to metal.

13. Provide fastener that when the spring clips are removed, the rail may be lifted vertically until it is completely free of the fastening shoulder without disturbing the horizontal or vertical alignment of the shoulder or the adjacent restraining rail bracket.

14. Dimensional and Shape Requirements:
   a. The fastener shall be rectangular or elliptical in shape. The frame and top plate shall include keying and/or turned up plate edges such that loss of elastomer bond shall not result in complete loss of the fasteners ability to hold line and gauge. The fastener should be designed to shed water without leaving pools.
   
   b. Height:
      1) The overall distance between the top surface of the plinth concrete and the rail base with the direct fixation fastener in the installed position shall be between 1-1/2-inches and 2-inches, exclusive of shims.
2) No part of the direct fixation fastener shall project more than 3-inches above the rail base in the installed position.

c. Length and Width:
   1) Fastener body dimensions including elastomer:
      a) Length: Measured perpendicular to the rail centerline, shall be between 13-1/2-inches and 16-inches.
      b) Width: Measured parallel to the rail centerline, shall be between 6-1/2-inches and 8-inches.
   2) No portion of the fastener in the installed position shall extend more than 9-inches toward the field side from the centerline of the running rail.

d. Adjustment Requirements:
   1) Lateral Adjustment:
      a) Plus or minus 1/4-inch, minimum, provided at the anchor bolts.
      b) Do not use friction as a means of preventing lateral movement.
      c) If lateral adjustment employs serrations on any component:
         i) Engage at least three serrations at interface.
         ii) Engage at least 3-inches of serration per fastener.
         iii) Machine or cast serrations to a minimum depth of 1/16-inch.
      d) Each rail fastener requires components for specified increments of lateral adjustment. Components of the direct fixation fastener shall not be replaced or added to the basic configuration to laterally adjust the rail.
      e) Provide 1/32-inch of lateral clearance between the rail seat and the rail for each direct fixation fastener.

C. Performance / Design Criteria:

   1. The spring rate for direct fixation fasteners shall be between 94,000 pounds per inch and 200,000 pounds per inch for vertical loads between 4,500 pounds and 12,000 pounds.

   2. Rail direct fixation fastener for 115 RE rail with longitudinal restraint between 2,000 and 3,500 pounds per rail seat.

   3. Restraining rail direct fixation fastener with longitudinal restraint between 2,000 and 3,500 pounds per rail seat. Fastener shall be able to accommodate a restraining rail bolted to the running rail.

   4. Electrical Isolation:
a. The fastener shall provide an electrical surface leakage distance not less than 1-3/4-inches measured from the grounded portion of the fastener to the charged portion by the most direct path that does not pass through an insulating material, and not less than 1/4-inch when measured passing through an insulating material.

b. The insulation requirements shall be met within the body of the fastener. No separate or detachable insulating components such as rail base pads or spring clip insulators shall be used.

c. No surface cut-outs, gaps, edge voids, or edge cut-outs will be allowed that could allow accumulation of dirt, metallic particles, or other material that could provide electrical leakage to ground.

d. Each fastener shall be furnished with a High Density Polyethylene shim as specified within the Contract Documents.

D. Materials:

1. Metal Components:
   a. Metal plate components shall be made from forged, cast steel or ductile iron.
      1) Cast steel: ASTM A148/A148M, Grade 80-40 or equal.
      2) Forged steel: ASTM A730, Grade C or equal.
      3) Ductile iron: ASTM A536, Grade 65-45-12 or equal.
   
   b. Corrosion Resistance Index: 4.0 minimum, calculated for rolled steel products and other steel with a chemical content within the composition range listed in ASTM G101 and containing less than 1.0 percent manganese.

2. Elastomer:
   a. Fabricated of 51 percent minimum natural rubber.
   b. The design Durometer Shore A shall be 50 plus or minus 10 for natural rubber as measured in accordance with ASTM D2240.
   c. Compressive strain of the elastomer: No more than 25 percent of its uncompressed thickness for a load of 14,000 pounds, applied vertically to the rail to a single fully assembled fastener. Include pre-compression of elastomer in fasteners in the installed position in determining the total compressive strain.
   d. Elastomeric component of the direct fixation fastener shall be fully vulcanize bonded to its frame and top plate and not less than 1/4-inch thick. The fastener shall also include bonded elastomer on its top surface to a plate.
   e. Water Absorption: ASTM D471
      1) Test Conditions: In accordance with ASTM D471.
      2) Acceptance Criteria: Water absorption after 24 hours immersion shall not exceed 0.5 percent.
f. Tensile Properties: ASTM D412
   1) Natural Rubber Tensile Strength: Minimum 2,500 pounds per square inch.
   2) Ultimate Elongation: Minimum 350 percent.

g. Resistance to Compression Set: ASTM D395, Method B
   1) Test Condition: Natural Rubber, 22 hours at 158 degrees Fahrenheit.
   2) Natural Rubber: Maximum 25 percent.

h. Resistance to Aging in Air: ASTM D573
   1) Test Condition: 72 hours at 158 degrees Fahrenheit.
   2) Natural Rubber, Retention of Tensile Strength: Minimum 75 percent.
   3) Retention of Ultimate Elongation: Minimum 75 percent.
   4) Change in Hardness: Maximum 10 points Durometer Shore A.

i. Resistance to Ozone Cracking: ASTM D1149
   1) Test Conditions: Specimens prepared in accordance with Procedure A of ASTM D1149 shall be tested in accordance with ASTM D1149 at a temperature of 104 degrees Fahrenheit and an ozone concentration of 50 parts per hundred million (pphm).
   2) Acceptance Criteria: Exhibit no cracking when examined in accordance with ASTM D1149 at the end of a 100 hour exposure.

j. Adhesion to Metal: ASTM D429, Method B
   1) Test Condition: Test specimen shall duplicate actual direct fixation fastener fabrication in respect to type of steel, preparation of steel, bonding agents, and elastomer.
   2) Acceptance Criteria: The failures of the elastomer shall be a type R failure, i.e., elastomer tears before bond fails.

k. Resistance to Oil: ASTM D471
   1) Test Condition: 70 hours at 74 degrees Fahrenheit in ASTM No. 1 oil.
   2) Acceptance Criteria: Volume change shall not exceed minus 10 percent or plus 20 percent.

l. Low Temperature Compression Set: ASTM D1229
   1) Test Condition: 70 hours at 14 degrees Fahrenheit.
   2) Acceptance Criteria: Compression at 30 minutes following release \(t_{30}\) reading): shall not exceed 65 percent.
m. Flame Spread and Smoke Generation: ASTM E162 and ASTM E662

1) Test Condition: Determine flame propagation index (Is) and smoke generation specific optical index (Ds) for flaming and non-flaming modes.

2) Acceptance Criteria: No flaming drippings when tested. No acceptance criteria are specified for the flame propagation index (Is) and smoke generation specific optical index (Ds). Report these indices to the Resident Engineer for information only.

n. Volume resistivity: ASTM D257

1) Test Condition: Apply 1,500 volts DC (minimum) for 3 minutes, and measure volume resistivity in accordance with ASTM D257.

2) Acceptance Criteria: Volume resistivity shall be at least $1 \times 10^{12}$ ohm-centimeters dry as molded and at least $1 \times 10^{11}$ ohm-centimeters after 24 hours immersion as determined below.

E. Fabrication:

1. Fabrication Tolerances:
   a. Length and Width: Plus or minus 1/16-inch
   b. Thickness: Plus or minus 0.03-inch
   c. Squareness: Plus or minus 1-degree (in a 360-degree circle)
   d. Centering of holes: Plus or minus 1/32-inch
   e. Diameter of holes: Plus or minus 1/16-inch
   f. Rail seat flatness: Plus or minus 1/32-inch

2.02 FASTENER SHIMS

A. Shape, size, and configuration of shims: Conform to the overall configuration of the direct fixation fastener with 1/2-inch extending beyond the fastener on all sides.

B. Shims shall be designed so that they can be simply installed and removed. Installation or removal shall not require the removal of the fastener body. The design shall incorporate a positive means of preventing the shims from displacement under operating conditions.

C. Shims shall be fabricated from black high density polyethylene and have matte finish.

2.03 ANCHOR INSERT ASSEMBLY

A. Anchor Bolts and Other Threaded Elements:

1. Threaded elements shall be high strength steel conforming to the chemical and mechanical requirements of ASTM A325, and having Class 2A and 2B thread fit. Thread length may vary from that specified for structural bolts.

2. Anchor bolts: 7/8-inch diameter, of sufficient length to provide a minimum of 2-inches of insert thread engagement with 1/2-inch of vertical shims under the rail fastener.

3. Threaded elements in the fastener shall include a positive means of preventing the loosening of the element due to in-service vibrations.
4. Anchor bolts shall not pre-compress the elastomer in the installed position.

5. Threaded element installation data shall include, but not be limited to, the bolt torque range in foot-pounds. The torque range shall provide the minimum tension as specified by the AISC Steel Construction Manual.

6. Bolts shall be coated with a water-resistant coating as thread protection against rusting prior to installation.

B. Anchor Inserts:

1. The anchor inserts shall, as a minimum, conform to ASTM A325, and shall have a Class 2B thread fit.

2. As part of the insert, there shall be a feature to prevent rotation of the insert after the concrete has reached its design strength.

3. The anchor insert shall have a minimum length of 4-1/2-inches and a maximum length of 5-1/2-inches and minimum 3-inch engaging threaded length.

4. In the installed position, the top of the anchor insert shall provide a flat surface parallel to the rail base with a minimum of 1/8-inch bearing width surrounding the anchor bolt hole.

5. Furnish with an installed plug of metal or plastic material to preclude the entrapment of moisture, concrete, or other foreign materials.
   a. Plug: Removable by socket or other common device and capable of reinsertion, and if reinserted, still preclude concrete and other foreign materials from entry.

6. Coated with a uniform epoxy resin insulating coating on exterior surfaces.
   a. 100 percent dry powder epoxy resin such as Scotch Kote Brand Protective Resin No. 323, manufactured by: the Minnesota Mining and Manufacturing Company (3M), and Corvel Epoxy ECB-1363A, manufactured by the Polymer Corporation, or approved equal.
   b. Before coating, the insert shall be degreased and cleaned to white metal in accordance with SSPC SP 5.
   c. Apply coating in accordance with the coating Supplier’s recommendations and the following general requirements, or an approved equal:
      1) No thinner than 10 mils or thicker than 20 mils.
      2) No runs, sags, or chips.
      3) Test thickness by a magnetic millimeters gauge at no less than two locations on the insert.
      4) Tested in accordance with ASTM D2440: hardness not less than 85 or more than 90 Shore D.
      5) Test coated insert for pin holes and breaks in a weak electrolytic solution:
         a) Immerse the coated insert in a weak electrolytic solution to within 1/4-inch of the top surface of inserts and contact a positive electrode with the non-coated, threaded, internal area of the insert. Place negative lead in the solution.
b) Electrolytic solution: potable water with resistivity maintained to within 1,000 to 1,500 ohm-cm.

c) Apply a 100 volt DC electrical current between the electrolyte and the insert.

d) Perform the testing at the frequency required in the sequential statistical quality control plan developed by the epoxy coating applicator.

e) Coating Acceptance Criteria: Circuit not closed when the insert is immersed in the electrolytic solution.

i) Average defective rate: Not more than 2 percent.

ii) Maximum defective rate: Not more than 5 percent.

iii) Demonstrate defective rates at a 90 percent degree of confidence.

2.04 RAIL FASTENING SPRING CLIPS

A. Spring clips shall be right-hand configuration.

B. Lateral rail position adjustment by the hold down assembly shall not be permitted.

C. Design shall not be dependent upon elastomeric components in torsion.

D. Installed into a fixed shoulder, integral to the fastener top plate.

E. Installed without the use of threaded elements.

F. No part of the clip shall protrude below the base of rail.

G. The clip shall not have point contact. The clip shall be such that lateral rail movements within the confines of the shoulders will not produce transverse denting, carving, or scoring of the rail base. The clip shall be such that longitudinal rail slippage will not produce overstressing, ending, twisting, or other damage to the clips, and will not damage the rail.

H. Design not to permit rail hold-down assembly or the means of preventing lateral movement of the rail to make point contact against the rail. If contact is made in the static or dynamic state, allow no less than 0.125-inch in dimension and no less than 0.15 square inch in area.

2.05 SOURCE QUALITY CONTROL

A. Rail Fastener Qualification and Production Testing: Qualification and production tests for each rail fastener are required. Comply with the following procedures for both qualification and production testing. Perform tests as shown in Figure 1A herein for qualification testing and in Figure 1B herein for production testing.

1. Qualification Testing: At the Contractor’s expense. Prior to production, select for testing two (2) direct fixation fasteners and two (2) restraining rail direct fixation fasteners for testing. Test each fastener as specified in Figure 1A, herein. Should any of the fasteners fail to meet the test requirements, test two (2) additional fasteners. In the event either of the two (2) additional fasteners fail, re-design the fastener, submit new Technical Data, and start the qualification test sequence over.
2. Production Testing: At the Contractor’s expense. Select for testing two (2) direct fixation fasteners from each 2,000 production lot fasteners. Test each fastener as specified in Figure 1B, herein. Should any of the fasteners fail to meet the test requirements, test two (2) additional fasteners of the same type from the production lot. In the event either of the two (2) additional fasteners fails, the entire lot shall be rejected or tested and only those successfully passing all tests shall be incorporated in the finished work.

3. Not less than fifteen (15) days prior to fastener shipments, certified statements for each elastomer batch used in the manufacture of the fasteners being delivered shall be submitted to the Resident Engineer documenting compliance of each elastomer batch with the requirements, as specified herein.

4. In addition to the qualification and production tests, components of the fasteners shall be subject to full or partial testing for compliance with the Contract Documents. The cost of additional testing of components that do not comply with the Contract Documents, shall be at no cost to Sound Transit.

5. Qualification and production testing may be performed at any testing facility in North America, including facilities at the Contractor’s plant. Testing equipment shall be in good repair, of adequate capacity, and shall be verified or calibrated against certified standards that have a known traceable relationship to the National Research Council or the National Institute of Standards and Technology. Notify the Resident Engineer not less than fifteen (15) days in advance of dates scheduled for tests.

6. Previous Qualification testing reports may be submitted to the Resident Engineer. Provided these reports are for an appropriate product with five (5) years of in-service history and past acceptable test results for Sound Transit, Qualification testing may be waived. Production testing shall be performed in all cases.

7. Submit six (6) copies of the production test results to the Resident Engineer at least fifteen (15) days prior to fastener shipment.

B. Static Tests: Perform each test listed below on two (2) specimens.

1. Vertical Load Test:
   a. Procedure: Apply a vertical load increasing in increments of 1,000 pounds to a maximum load of 14,000 pounds at a rate not less than 500 pounds per minute and not more than 2,000 pounds per minute. Load shall be applied downward at the center of the rail head at the centerline of the fastener normal to the rail. For each increment of load, measure the vertical deflection of the rail head to the nearest 0.001-inch. Remove the load and measure and record the final position of the rail head. Plot the recorded values for vertical loads versus deflection on a graph, as shown in Figure 3, herein. Pre-cycle the fasteners by loading from 0 to 14,000 pounds two (2) times prior to measuring deflections.

   b. Test Acceptance Criteria:

      1) The load versus deflection curve: within the envelope shown in Figure 3 for loads in the range from 4,500 pounds to 12,000 pounds.

      2) The spring rate of the fastener (slope of the load-deflection curve) shall not be less than 94,000 pounds per inch or more
than 200,000 pounds per inch for loads between 4,500 pounds and 12,000 pounds.

a) Calculate the spring rate by applying the least-squares linear regression method to the recorded data to obtain a straight line load-deflection relationship.

b) Each recorded deflection shall be within 10 percent of the deflection calculated from the straight-line relationship over the loading range, from 4,500 pounds to 12,000 pounds.

c) After removal of the maximum load, the fastener shall return to within 0.005-inch of its original position within 1 minute.

3) At no time during the test shall any fastener component exhibit any sign of failure by slippage, yielding, or fracture. Slippage is defined to mean any movement of the fastener components relative to the initial position not attributed to deflection or yielding. The deflection measured at 14,000 pounds divided by the design thickness of the elastomer component shall be used to establish the fastener’s compliance with the requirement for a maximum vertical deflection not to exceed 25 percent of the elastomer thickness. The values obtained when this test is repeated on all fasteners shall be within 20 percent of the initial test values.

2. Lateral Load Test:

a. Procedure: While applying a vertical load of 12,000 pounds downward, offset 3/4-inch from the center of the rail head towards the gauge side at the centerline of the fastener normal to the rail, apply a lateral load horizontally to the rail head at a point 0.625-inch below the top of the rail along the centerline of the fastener in a direction normal to the rail. Increase the load in increments of 1,000 pounds to a maximum load of 8,000 pounds, at a rate of not less than 500 pounds per minute and not more than 1,500 pounds per minute. For each load increment, measure the lateral deflection of the rail head at a point 0.625-inch below the top of the rail to the nearest 0.001-inch and record.

b. Remove the lateral load and measure and record the final position of the rail head. Plot the recorded values for lateral loads versus deflection on a graph similar to Figure 3, herein.

c. Test Acceptance Criteria:

1) The lateral deflection of the rail head for a lateral load of 4,000 pounds shall not exceed 0.15-inch.

2) The lateral deflection due to the maximum load: shall not exceed 0.37-inch.

3) Difference between the original and final positions of the rail head shall not exceed 0.027-inch.

4) No fastener component at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture.
3. **Longitudinal Restraint Test:**
   
a. Procedure: Support the rail end on a roller or other low friction support properly elevated to prevent the longitudinal load from binding the rail in the fastener. Apply load longitudinally to the rail at its base increasing in increments of 500 pounds to a maximum load of 10,000 pounds or until the rail is 2-inches from the initial position at a rate not less than 500 pounds per minute and not more than 1,500 pounds per minute. Each load increment shall be maintained until the longitudinal movement of the rail stops before increasing the load to the next increment. For each load, measure the longitudinal movement of the rail in relation to the top plate of the rail fastener to the nearest 0.01-inch and record. Remove the longitudinal load at slippage, measure and record the final position of the rail in relation to the top plate of the rail fastener. Measure and record the load applied at slippage for use in the Push-Pull Test, as specified herein. Plot the recorded values for longitudinal load versus movement on a graph as shown in Figure 3, herein and identify it as “Initial Test.” Without altering test set-up, apply the load to the opposite end of the test rail and re-run the test in its entirety. Plot the recorded values for longitudinal load versus movement on a graph as shown in Figure 3, herein, and identify it as “Reverse Test.”

b. **Test Acceptance Criteria:**
   
   1) Longitudinal load versus deflection curve, when plotted on Figure 4: entirely within the limits defined by limit lines A and B.

   2) Difference between the original (before initial test) and final (after reverse test) position of the rail: not to exceed the total rail slippage plus 0.24-inch.

   3) No fastener component at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture except that slippage which may occur between the rail hold-down assembly and the rail.

   4) Rail hold-down assembly longitudinal restraint: constant, uniform, and unbroken curve, which falls within the envelope shown in Figure 4 herein when plotted.

   5) At least 85 percent of test results shall fall within limits A and B.

4. **Lateral Restraint Test:**
   
a. Procedure: Apply two (2) lateral loads, each increasing simultaneously in increments of 500 pounds to a maximum load of 2,500 pounds at the base of the rail, in the same direction, normal to the centerline of the rail and symmetrically on each side of the fastener centerline. Measure the lateral deflection of the rail at the intersection of the centerline of the fastener and the gage line of the rail to the nearest 0.001-inch and record after each increment of loading.

b. **Test Acceptance Criteria:**
   
   1) No fastener component at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture.

   2) Difference between the original and final positions of the gage line: not to exceed 0.062-inch.
3) Lateral deflection of the rail, when fully loaded: between 0.03-inch and 0.125-inch from the original gage line of the rail.

5. Vertical Uplift Test:
   a. Procedure: Apply and secure a vertical load to the center of the rail head at the centerline of the fastener in a direction normal to the rail, alternating continually from a vertical downward load to a vertical upward load. Increase the upper and lower peaks per cycle in increments of 200 pounds to a maximum of 5,000 pounds downward and upward. Continually measure the loads and deflections to the nearest 0.001-inch and immediately record on a load-versus-time graph and deflection-versus-time graph, respectively. Remove the load and measure and record the final position of the rail head. Apply the reaction force to the uplift load by only securing the test block on which the fastener is mounted.
   b. Test Acceptance Criteria:
      1) Vertical deflection of the fastener for lifting load of 2,000 pounds: within 105 percent to 205 percent of the deflection for a 2,000 pound downward vertical load as determined from the vertical load test.
      2) While vertical load is continuously varied from vertical downward loads to vertical uplift loads, the load-deflection curve shall be continuous and there shall be no other indication of backlash or freeplay at times when the load or the deflection changes direction.
      3) After removal of the maximum load, the rail shall immediately return to within 0.005-inch of its original position within 1 minute.
      4) No fastener components including the fastener anchor insert to the test block at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture.

C. Electrical Tests: Perform each test listed below on two (2) specimens.

1. Voltage Withstand Test:
   a. Procedure: A complete, fully assembled fastener, configured as specified, shall have a ground plate placed below the elastomer. A DC potential of 10 kilovolts shall be applied to the rail head for 1 minute. In the event of breakdown, record the breakdown voltage.
   b. Test Acceptance Criteria: The elastomer shall complete this test with no visible damage such as splits, cracks, pinholes, or fractures. Perform all other electrical tests on the fastener.

2. Electrical Resistance Tests:
   a. Procedure: Test a complete, fully assembled fastener, as specified herein, for electrical resistance. Before assembly, metal parts, anchor insert, spring clips, elastomer surfaces, and ancillary parts associated with the fastener shall be clean and dry. Assemble the fastener with a section of 115 pound RE rail, not less than 1-foot in length. Mount the test fastener on a 1/4-inch thick metallic ground plate sized to extend 1/2-inch beyond all edges of the fastener. Use anchor insert assemblies supplied, or similar to that for use in actual field installation, to mount the
fastener to the ground plate. Use the same number of bolts (or other devices) that will be used to anchor the fastener in-service. Verify that all parts that should be in electrical contact do not exhibit excessive contact resistance because of improper assembly or other causes. This shall apply, but is not necessarily limited to:

1) Rail to rail plate interface

2) Rail hold-down assembly (clip) and rail

3) Anchor bolts and bottom fastener plate (if present)

4) Anchor bolts and ground plate.

b. Dry conditions: 24 hours prior to testing, store the assembled fastener(s) in a clean, dry environment with ambient conditions of 60 degrees Fahrenheit to 80 degrees Fahrenheit and 50 to 70 percent relative humidity. Apply 100 volts (minimum) DC between the rail head and the ground plate for 3 minutes. Measure the applied voltage and resulting current flow, or directly measure the resistance with an accuracy flow, or directly measure the resistance with an accuracy of plus or minus 2 percent. Instrumentation used for direct measurement shall have a minimum 100 volt output capacity.

c. Wet conditions: Perform this test on the same fastener(s) that passed the dry electrical resistance tests. Place the assembled fastener in a nonmetallic trough or other suitable container. Size the container such that there is a minimum of 2-inches between the sides and bottom of the fastener/ground plate assembly and the sides and bottom of the container. In the event more than one (1) fastener is placed in the same container, maintain a 2-inch clearance between the edges of the ground plates on adjacent fasteners and the clearances cited above. Pour water into the container to a level midway up the rail web covering all surfaces of the fastener. Maintain this level of immersion for 72 hours. Ambient temperature of fastener surfaces (prior to immersion) of water, and air shall be 60 to 80 degrees Fahrenheit. Relative humidity shall be 50 to 70 percent. Water resistivity shall be 1,000 to 1,500 ohm-cm (use potable water and adjust resistivity by addition of sodium chloride). Drain the water from the container to a level 1/2-inch below the ground plate. Without drying or otherwise disturbing the fastener or creating a condition that causes the fastener surfaces to dry, measure the resistance within 15 seconds after draining as follows:

1) Apply 100 volts between the rail head and the ground plate for 15 seconds.

2) Measure the applied voltage and resulting current flow with an accuracy of plus or minus 2 percent. Calculate the DC wet resistance, or directly measure the resistance with an accuracy of plus or minus 2 percent. Ensure instrumentation used for direct measurement have a minimum 100 volt measuring capacity.

3) Repeat the resistance measurement every 5 minutes for the first hour, every 10 minutes for the second hour, and every 15 minutes thereafter to establish the wet resistance versus time characteristics of the fastener. Perform tests for at least 2 hours after draining. The tests may be terminated after the 2 hour test period when any three (3) consecutive measurements are at
least 800,000 ohms or after another 2 hour test period, whichever comes first.

d. Test Acceptance Criteria:

1) Dry conditions: The minimum DC resistance shall be 10 megohms.

2) Wet conditions: A minimum resistance of 800,000 ohms for the average of three (3) consecutive readings within 2 hours after wetting.

   a) Average difference between each of the three (3) readings: not exceed 10 percent of the average.

3. Electrical Impedance Tests:

a. Procedure: Test a complete, fully assembled fastener for electrical impedance. Apply a potential of 50 volts AC RMS to the rail head for 3 minutes for each increment of measurement for frequencies from 10 hertz to 10 kilohertz in increments of 20 hertz up to 100 hertz, 200 hertz up to 1,000 hertz, and 2,000 hertz up to 10 kilohertz. Measure the impedance after 3 minutes with an accuracy of plus or minus 2 percent and record each frequency. Upon approval by the Resident Engineer, electrical resistance may be calculated by measuring current flow, and impedance may be calculated from the measurements of resistance and capacitance using the impedance equation, which applies to a resistance and capacitance in parallel.

   1) Test Acceptance Criteria: The minimum impedance for any frequency between 20 hertz and 10 kilohertz with 50 volts AC RMS: 10,000 ohms.

D. Dynamic Tests: Perform each test listed below on two (2) specimens.

1. Dynamic to Static Stiffness Ratio Test:

a. Procedure. Apply vertical (compression) load to the rail head over the centerline of the fully assembled fastener. The load shall be of sinusoidal waveform over a range from 3,000 pounds to 7,000 pounds and shall be applied at a rate of 10 to 20 cycles per second. After a minimum of 1,000 cycles, measure and record the dynamic deflection of the fastener at 3,000 pounds and 7,000 pounds. Immediately after completing the dynamic deflection measurements, but only after the fastener deflection has stabilized, measure the static deflection at compression loads from 3,000 pounds to 7,000 pounds in 1,000 pound increments at a rate not exceeding 1,000 pounds per minute. Measure the deflections within an accuracy of 0.001-inch.

b. Test Acceptance Criteria:

   1) Dynamic stiffness: Calculated by dividing the difference between the recorded maximum and minimum load value (the dynamic load) by the difference between the recorded maximum and minimum deflection (the dynamic deflection).

   2) Static stiffness: Calculated by applying the least-squares linear regression method to the recorded data to obtain a straight line and determining the slope of the static load-deflection curve.
3) The ratio shall not exceed 1.5.

2. Vertical and Lateral Repeated Load Test:
   a. Procedure. Apply loads to the rail head in such a manner as to produce a vertical downward load of 12,000 pounds, and lateral loads along the centerline of the fastener normal to the rail of 3,900 pounds to the gauge side of the rail head and 2,700 pounds to the field side of the rail head. Apply the vertical load to the rail head and the lateral loads shall be applied 0.625-inch below top of rail along the centerline of each fastener normal to the rail. Alternate application of the lateral loads, each combined with alternating application and release of the vertical load, for a total of 3,000,000 complete cycles for qualification testing or a total of 500,000 cycles for production testing. Application of the field side load and vertical load and then the gauge side load and vertical load shall constitute one (1) cycle. The frequency shall be regulated to prevent the temperature of the components from exceeding 158 degrees Fahrenheit. Do not re-torque threaded elements subsequent to the completion of the initial 500,000 cycles of loading without written approval from the Resident Engineer.
   b. Test Acceptance Criteria:
      1) Withstand the 3,000,000 cycles for qualification testing or 500,000 cycles for production testing of load application with no evidence of failure.
      2) Upon complete disassembly of the fastener and visual inspection, no fastener components shall exhibit any sign of failure by slippage, yielding, abrasion, or fracture.
      3) No evidence of wear or grooving on the rail that would contribute to a failure of the rail.
      4) Concrete test block at the anchor insert: no evidence of failure as a result of the dynamic test.

3. Anchor Bolt Repeat Load Test:
   a. Procedure: After completion of the Vertical and Lateral Repeated Load Test, reassemble the fastener as specified using only the original components previously subjected to testing. With the gauge side anchor bolt loosened such that a minimum gap of 1/4-inch is between the underside of the bolt head and the anchor washer, repeat the Vertical and Lateral Repeated Load Tests for 15,000 cycles.
   b. Test Acceptance Criteria:
      1) Fastener: Withstand 15,000 cycles of loading with no evidence of failure by slippage, yielding, or fracture.
      2) Rail: No evidence of wear or grooving that would contribute to a failure of the rail.

4. Push-Pull Test:
   a. Procedure: Apply a cycling longitudinal load as close to the base of the rail as possible to slip the rail plus and minus 3/4-inch from the initial position of the fastener and relative to the fastener position, for a total of 50 cycles.
b. Immediately following this portion of the test, apply a cycling longitudinal load equal to 80 percent of the load recorded in the Longitudinal Restraint Test, as specified herein, shall be applied as in the procedure above for a total of 25,000 cycles. Do not reposition the rail hold-down assemblies at any time during this test.

c. Test Acceptance Criteria: Withstand the 25,000 cycles of loading with no evidence of failure. Upon visual examination, no component of the fastener shall exhibit any evidence of failure by yielding, abrasion, slippage or fracture, except that slippage which may occur between the rail hold-down assembly and the rail. The rail shall exhibit no evidence of wear or grooving that would contribute to a failure of the rail.

5. Uplift Repeated Load Test:

a. Procedure: Apply loads to the rail head of a fully assembled fastener to produce alternately a vertical downward load of 9,000 pounds and a vertical upward load of 1,000 pounds at the centerline of the fastener in a direction normal to the rail. Alternate the application of the vertical loads for a total of 1,500,000 complete cycles. Regulate the frequency to prevent component temperature from exceeding 158 degrees Fahrenheit. Do not re-torque threaded elements without written approval from the Resident Engineer. Apply the vertical loading during this part of the test at a rate of not less than 25 cycles per minute. If required for testing stability, install a mechanical stop 1/8-inch from each end of the rail, independent of the test rail fasteners.

b. Test Acceptance Criteria: Withstand 1,500,000 cycles of load application with no evidence of failure. Upon visual inspection, no component of the fastener shall exhibit any evidence of failure by yielding, abrasion, or fracture. The rail shall exhibit no evidence of wear or grooving that would contribute to the failure of the rail.

6. Dynamic Longitudinal Restraint Test:

a. Procedure: The dynamic longitudinal restraint test procedure is the same as for the static test specified herein, with an additional vibration load applied vertically to the rail head while the longitudinal load is applied. Vertical vibration load: 50 hertz cyclic load with amplitude of 2,000 pounds. Apply vertical load at the rail head at the mid-point between rail seats.

b. Test Acceptance Criteria:

1) Longitudinal load versus deflection plot is linear within the limits shown in Figure 3, herein. At no time during the test shall any component exhibit evidence of failure including permanent deformation.

E. Anchor Insert Tests:

1. General:

a. Anchor inserts used for testing shall conform to the design submitted by the Contractor and approved by the Resident Engineer.

b. Production anchor inserts shall be used for tests unless prototype model testing is approved in writing by the Resident Engineer. Before Resident Engineer approval, the Contractor shall submit data showing that the prototype will react in the tests as would the production models. Should
prototype testing qualify the anchor inserts design, four (4) production models shall be tested immediately after production is started. Should a production model fail the test, the entire anchor inserts test series shall be repeated using production models. Such tests shall be done at the same laboratory as the earlier tests.

2. Test Conditions: Fourteen (14) test anchor inserts for each anchor shall be furnished by the Contractor. Seven (7) assemblies shall be retained by the Resident Engineer and the other seven (7) assemblies shall be numbered one through seven. Anchor inserts two through seven shall be tested in cast concrete plinth as shown on the Contract Drawings, utilizing the minimum plinth dimensions and specified reinforcement. Concrete shall have a compressive strength in accordance with cast-in-place concrete requirements as stated elsewhere in the Contract Documents, and this shall be verified by laboratory tests. Anchor inserts shall be placed in the concrete plinth in accordance with the Contract Drawings.

3. Static Load Tests:
   a. Thread Failure Test (Anchor Insert Number 1):
      1) Procedure: Anchor insert shall be held in a vise or other device and the bolt twisted to failure. To prevent bottoming before failure, the bolt shall be fitted with a spacer, cut washers, or other means. To provide minimum thread contact only, the spacer thickness shall be designed such that the minimum thread is engaged.
      2) Test Acceptance Criteria: Anchor insert shall withstand 600 foot-pounds of torque without evidence of failure. After removal of the torque, the bolt shall be removed from the insert with a torque no greater than 600 foot-pounds. When torqued to failure, the failure shall be in the bolt threads, not the insert threads.
   b. Torsion Test (Anchor Inserts Numbers 2 and 3):
      1) Procedure: Anchor insert shall be subjected to a 600 foot-pound of torque applied to the cap bolt head with spacers used on the bolt to prevent bottoming.
      2) Test Acceptance Criteria: Anchor insert shall not rotate and concrete shall not crack or show evidence of failure.
   c. Restrained Pull-Out Test (Anchor Inserts Numbers 4 and 5):
      1) Procedure: A steel plate with a hole in the center 1/2-inch in diameter larger than the maximum diameter of the top of the insert shall be placed over the anchor inserts on the concrete test block surfaces. The anchor bolt shall then have an upward vertical load of 20,000 pounds applied, held for a minimum of 1 minute, and then released.
      2) Test Acceptance Criteria: Anchor insert shall have no evidence of failure from causes including but not limited to, slippage and cracking of the concrete at the indicated load.
   d. Unrestrained Pull-Out Test (Anchor Inserts Numbers 6 and 7):
1) Procedure: Anchor insert shall have an upward vertical load applied in such a manner that no vertical load is applied to the concrete test block surface within a radius of 6 inches from the center of the insert. An upward vertical load of 10,000 pounds shall be applied and held for not less than 1 minute.

2) Test Acceptance Criteria: There shall be no evidence of failure from causes including, but not limited to, slippage, and cracking of the concrete to assembly bond at the specified loads.

2.06 FIGURES
A. Figure 1A - Qualification Tests
B. Figure 1B - Production Tests
C. Figure 2 - Vertical Deflection Limits
D. Figure 3 - Longitudinal Restraint Limits

PART 3 - EXECUTION
3.01 INSTALLATION
A. Direct fixation fasteners shall be installed in accordance with track construction requirements as stated elsewhere in the Contract Documents.

END OF SECTION
### Qualification Tests (QT)

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**Note:**

- **Sections:** 34.11.36.13
- **Figure:** 1B
- **2018 Standard Specifications**
- **Page:** 22 of 24
NOTES:

1. MAXIMUM DEFLECTION AT 14,000 LBS. SHALL NOT EXCEED 25% OF THE UNCOMPRESSED THICKNESS OF ELASTOMER PAD.

2. FASTENER SPRING RATE MUST BE BETWEEN 94,000 LBS./IN. AND 200,000 LBS./IN. FOR ALL LOADS BETWEEN 4,500 LBS. AND 12,000 LBS.
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for furnishing all labor, materials, and equipment for manufacturing, testing, fabricating, and delivering high-resilient (HR) direct fixation fasteners including standard and with restraining rail, as specified within the Contract Documents.

B. This Section shall serve as a performance specification for the HR direction fixation fasteners.

C. Utilize one basic HR direct fixation fastener assembly for standard rail fasteners, and one basic HR direct fixation fastener assembly for restraining rail fasteners, and comply with the configuration and requirements in the Contract Documents.

1.02 REFERENCES

A. This Section incorporates by reference the latest revision of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   a. AREMA Manual for Railway Engineering (AREMA Manual)

2. American Institute of Steel Construction (AISC)
   a. AISC Steel Construction Manual

3. ASTM International (ASTM)
   a. ASTM A36/A36M Standard Specification for Carbon Structural Steel
   d. ASTM F3125/F3125M Standard Specification for High Strength Structural Bolts, Steel and Alloy Steel, Heat Treated, 120 ksi (830 MPa) and 150 ksi (1040 MPa) Minimum Tensile Strength, Inch and Metric Dimensions
   e. ASTM A536 Standard Specification for Ductile Iron Castings
   f. ASTM A730 Standard Specification for Forgings, Carbon and Alloy Steel, for Railway Use
   g. ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials
h. ASTM D395 Standard Test Methods for Rubber Property - Compression Set
i. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension
j. ASTM D429 Standard Test Methods for Rubber Property - Adhesion to Rigid Substrates
k. ASTM D471 Standard Test Method for Rubber Property - Effect of Liquids
l. ASTM D573 Standard Test Method for Rubber - Deterioration in an Air Oven
m. ASTM D1149 Standard Test Methods for Rubber Deterioration - Cracking in an Ozone Controlled Environment
n. ASTM D1229 Standard Test Method for Rubber Property - Compression Set at Low Temperatures
o. ASTM D2240 Standard Test Method for Rubber Property - Durometer Hardness
q. ASTM E662 Standard Test Method for Specific Optical Density of Smoke Generated by Solid Materials

4. The Society for Protective Coatings (SSPC)
a. SSPC SP 5 White Metal Blast Cleaning

1.03 SUBMITTALS
A. Technical Data: Include shop drawings for each fastener and all information including details showing dimensions, arrangement, and material description for each component in fastener assembly.

B. Product Data: Product data, catalog cuts, drawings, material specifications, and installation instructions for each component in the fastener assembly and furnished products.

C. Samples:
1. Transmit two (2) identical samples of the HR direct fixation fastener.
2. Label each sample indicating:
   a. Contract Name and Number
   b. Name of Contractor and Subcontractor
   c. Material or equipment represented
   d. Source
e. Name of manufacturer and brand  
f. Reference specifications section and article numbers

D. Qualification Statement: Transmit documentation pertaining to fasteners' conformance to the requirements as specified herein. Document shall include Contractor's certification that furnished products meet specified requirements.

E. Certifications:  
   1. Transmit rail clip Supplier's approval of rail hold-down spring clip application on proposed HR direct fixation fastener as specified herein.  
   2. Transmit certification of each elastomer batch used as specified herein.

F. Transmit threaded element installation data as specified herein.

G. Transmit Direct Fixation Fastener Testing: Provide test results documentation as required for the Work as specified herein.

H. Submit a detailed narrative explaining the Quality Control Program and description of procedures to be utilized for the Work and a description of the organization to be used on the Contract.

1.04 QUALITY ASSURANCE

A. Develop and maintain a quality control program regulating methods, procedures, and processes to ensure compliance with standards of quality required by the Contract Documents.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Fasteners shall be packed and shipped in a manner that shall prevent a load on any fastener from exceeding 1,000 pounds.

B. Fasteners shall not be stored by the Contractor in a wet location or where the ambient temperature will exceed 120 degrees Fahrenheit.

C. Fasteners and assemblies shall be packaged to permit outdoor storage.

D. Fastener bodies shall be palletized and banded. Rail hold-down assemblies, shoulders, bolts, nuts, and other loose items shall be packaged by component type in secure shipping kegs, boxes, or bags. All items shall be clearly identified as to the contents.

E. Damage: Replace fasteners and assemblies damaged during packaging, shipping, storage, and handling. Special care shall be taken to protect the threaded lengths of bolts to prevent damage.

PART 2 - PRODUCTS

2.01 HIGH-RESILIENT DIRECT FIXATION FASTENER

A. Manufacturers:
   1. HR direct fixation fasteners manufactures are required to have five years of direct fixation fastener in-service performance history.

B. Fastener Description:
1. The HR direct fixation fastener shall be for 115 RE rail, with spring clips in the right-hand configuration.

2. Provide, on both sides of the rail base, a positive means of preventing more than 1/8-inch total lateral movement of the rail base relative to the shoulders in case of failure or loosening of one or both spring clips.

3. The lateral rail restraint shall extend a minimum of 3/8-inch vertically, but not higher than 1-3/4-inches above the base of rail in the installed position.

4. The HR direct fixation fastener shall utilize a spring clip type element with non-threaded components to form the rail hold down assembly, fasteners shall utilize the Pandrol PR 601A or approved equal.

5. The assembled direct fixation fasteners shall provide a canted rail seat to provide a 40 to 1 rail cant when mounted to a flat, level surface. Assembled direct fixation fasteners tapered rail seat shall be towards the centerline of the track.

6. Two anchorage insert assemblies per fastener, for securing the direct fastener to the plinth concrete.

7. HR direct fixation fasteners shall be composed of as few components as is economically and technically practicable for ease of assembly, disassembly, and maintenance, and shall be designed to permit installation and replacement of the entire assembly or its components by one worker using standard conventional hand tools.

8. HR direct fixation fastener shall be designed to dampen lateral and vertical dynamic forces transferred to anchor bolts.

9. In its installed position, the underside of the fastener shall be a flat plane. Base protrusions into the plinth concrete will not be allowed.

10. Bonding of the HR direct fixation fastener to the plinth concrete shall not be permitted.

11. Fastener plates shall have full bearing on the elastomer in positions of lateral adjustment and have a means of preventing displacement of the elastomer.

12. Stability of the fastener shall not be dependent solely upon the strength of bonding of the elastomer to metal.

13. Provide fastener that when the spring clips are removed, the rail may be lifted vertically until it is completely free of the fastening shoulder without disturbing the horizontal or vertical alignment of the shoulder or the adjacent restraining rail bracket.

14. Dimensional and Shape Requirements:

   a. The fastener shall be rectangular or elliptical in shape. The frame and top plate shall include keyed and/or turned up plate edges such that loss of elastomer bond shall not result in complete loss of the fasteners ability to hold line and gauge. The fastener should be designed to shed water without leaving pools.

   b. Height:

      1) The overall distance between the top surface of the plinth concrete and the base of the rail with the HR direct fixation
fastener in the installed position shall be between 1-7/8-inches and 2-7/8-inches, exclusive of shims.

2) No part of the HR direct fixation fastener shall project more than 3-1/2-inches above the rail base in the installed position.

c. Length and Width:

1) Fastener body dimensions including elastomer:
   a) Length: Measured perpendicular to the rail centerline, shall be between 13-1/2-inches and 17-1/2-inches
   b) Width: Measured parallel to the rail centerline, shall be between 6-1/2-inches and 9-inches

2) No portion of the fastener in the installed position shall extend more than 9-inches toward the field side from the centerline of the running rail.

d. Adjustment Requirements:

1) Lateral Adjustment:
   a) Plus or minus 1/4-inch, minimum, provided at the anchor bolts.
   b) Do not use friction as a means of preventing lateral movement.
   c) If lateral adjustment employs serrations on any component:
      i) Engage at least three serrations at interface.
      ii) Engage at least 3-inches of serration per fastener.
      iii) Machine or cast serrations to a minimum depth of 1/16-inch.
   d) Each rail fastener requires components for specified increments of lateral adjustment. Components of the direct fixation fastener shall not be replaced or added to the basic configuration to laterally adjust the rail.
   e) Provide 1/32-inch of lateral clearance between the rail seat and the rail for each direct fixation fastener.

C. Performance / Design Criteria:

1. The spring rate for HR direct fixation fasteners shall be between 40,800 pounds per inch and 61,200 pounds per inch for vertical loads between 2,000 pounds and 10,000 pounds.

2. HR direct fixation fastener shall have a longitudinal restraint between 1,800 and 3,000 pounds per rail seat.
3. Restraining rail HR direct fixation fastener with longitudinal restraint between 1,800 and 3,000 pounds per rail seat. Fastener shall be able to accommodate a restraining rail bolted to the running rail.

4. HR direct fixation fasteners shall be designed to provide vibration isolation in three axis and be suited for installation with minimal changes to the proposed track construction.

5. Electrical Isolation:
   a. The fastener shall provide an electrical surface leakage distance not less than 1-3/4-inches measured from the grounded portion of the fastener to the charged portion by the most direct path that does not pass through an insulating material, and not less than 1/4-inch when measured passing through an insulating material.
   b. The insulation requirements shall be met within the body of the fastener. No separate or detachable insulating components such as rail base pads or spring clip insulators shall be used.
   c. No surface cut-outs, gaps, edge voids, or edge cut-outs will be allowed that could allow accumulation of dirt, metallic particles, or other material that could provide electrical leakage to ground.
   d. Each fastener shall be furnished with a High Density Polyethylene shim as specified within the Contract Documents.

D. Materials:

1. Metal Components:
   a. Metal plate components shall are be made from forged, cast steel or ductile iron.
      1) Cast steel shall be ASTM A148/A148M, Grade 80-40 or equal.
      2) Forged steel shall be ASTM A730, Grade C or equal.
      3) Ductile iron shall be ASTM A536, Grade 65-45-12 or equal.
   b. A Corrosion Resistance Index: 4.0 minimum, calculated for rolled steel products and other steel with a chemical content within the composition range listed in ASTM G101 and containing less than 1.0 percent manganese.

2. Elastomer:
   a. Fabricated of 51 percent minimum natural rubber
   b. The design Durometer Shore A shall be 50 plus 10 for natural rubber as measured in accordance with ASTM D2240.
   c. Compressive strain of the elastomer: No more than 25 percent of its uncompressed thickness for a load of 14,000 pounds, applied vertically to the rail to a single fully assembled fastener. Include pre-compression of elastomer in fasteners in the installed position in determining the total compressive strain.
d. Elastomeric component of the HR direct fixation fastener shall be fully vulcanize bonded to its frame and top plate and not less than 1/2-inch thick. The fastener shall also include bonded elastomer on its top surface to a plate.

e. Water Absorption: ASTM D471
   1) Test Conditions: In accordance with ASTM D471.
   2) Acceptance Criteria: Water absorption after 24 hours immersion shall not exceed 0.5 percent.

f. Tensile Properties: ASTM D412
   1) Natural Rubber - Tensile Strength: Minimum 2,500 pounds per square inch.
   2) Ultimate Elongation: Minimum 350 percent.

g. Resistance to Compression Set: ASTM D395, Method B
   1) Test Condition: Natural Rubber, 22 hours at 158 degrees Fahrenheit.
   2) Natural Rubber: Maximum 25 percent.

h. Resistance to Aging in Air: ASTM D573
   1) Test Condition: 72 hours at 158 degrees Fahrenheit.
   2) Natural Rubber - Retention of Tensile Strength: Minimum 75 percent.
   3) Retention of Ultimate Elongation: Minimum 75 percent.
   4) Change in Hardness: Maximum 10 points Durometer Shore A.

i. Resistance to Ozone Cracking: ASTM D1149
   1) Test Condition: Specimens prepared in accordance with Procedure A of ASTM D1149 shall be tested in accordance with ASTM D1149 at a temperature of 104 degrees Fahrenheit and an ozone concentration of 50 parts per hundred million (pphm).
   2) Acceptance Criteria: Exhibit no cracking when examined in accordance with ASTM D1149 at the end of a 100 hour exposure.

j. Adhesion to Metal: ASTM D429, Method B
   1) Test Condition: Test specimen shall duplicate actual HR direct fixation fastener fabrication in respect to type of steel, preparation of steel, bonding agents, and elastomer.
   2) Acceptance Criteria: The failure of the elastomer shall be type R failure, i.e., elastomer tears before bond fails.

k. Resistance to Oil: ASTM D471
1) Test Condition: 70 hours at 74 degrees Fahrenheit in ASTM No. 1 oil.

2) Acceptance Criteria: Volume change shall not exceed minus 10 percent or plus 20 percent

i. Low Temperature Compression Set: ASTM D1229

1) Test Condition: 70 hours at 14 degrees Fahrenheit.

2) Acceptance Criteria: The compression at 30 minutes after release (t_{30} reading) shall not exceed 65 percent.

m. Flame Spread and Smoke Generation: ASTM E162 and ASTM E662

1) Test Condition: Determine flame propagation index (Is) and smoke generation specific optical index (Ds) for flaming and non-flaming modes.

2) Acceptance Criteria: No flaming drippings when tested. No acceptance criteria are specified for the flame propagation index (Is) and smoke generation specific optical index (Ds). Report these indices to the Resident Engineer for information only.


1) Test Condition: Apply 1500 volts DC (minimum) for 3 minutes, and measure volume resistivity in accordance with ASTM D257.

2) Acceptance Criteria: The volume resistivity shall be at least 1 x 10^{12} ohm-centimeters dry as molded and at least 1 x 10^{11} ohm-centimeters after 24 hours immersion as determined below.

E. Fabrication:

1. Fabrication Tolerances:

   a. Length and Width: Plus or minus 1/16-inch

   b. Thickness: Plus or minus 0.03-inch

   c. Squareness: Plus or minus 1-degree (in a 360-degree circle)

   d. Centering of holes: Plus or minus 1/32-inch

   e. Diameter of holes: Plus or minus 1/16-inch

   f. Rail seat flatness: Plus or minus 1/32-inch

2.02 FASTENER SHIMS

A. Shape, size, and configuration of shims: Conform to the overall configuration of the HR direct fixation fastener with 1/2-inch extending beyond the fastener on all sides.

B. Shims shall be designed so that they can be simply installed and removed. Installation or removal shall not require the removal of the fastener body. The design shall incorporate a positive means of preventing the shims from displacement under operating conditions.

C. Shims shall be fabricated from black high density polyethylene and have matte finish.
2.03 ANCHOR INSERT ASSEMBLY

A. Anchor Bolts and Other Threaded Elements:

1. Threaded elements shall be high strength steel conforming to the chemical and mechanical requirements of ASTM A325, and having Class 2A and 2B thread fit. Thread length may vary from that specified for structural bolts.

2. Anchor bolts: 7/8-inch diameter, of sufficient length to provide a minimum of 2-inches of insert thread engagement with maximum 1/2-inch of vertical shims under the HR direct fixation fastener.

3. Threaded elements in the fastener shall include a positive means of preventing the loosening of the element due to in-service vibrations.

4. Anchor bolts shall not pre-compress the elastomer in the installed position.

5. Threaded element installation data shall include, but not be limited to, the bolt torque range in foot-pounds. The torque range shall provide the minimum tension as specified by the AISC Steel Construction Manual.

6. Bolts shall be coated with a water-resistant coating as thread protection against rusting prior to installation.

B. Anchor Inserts:

1. The anchor inserts shall, as a minimum, conform to ASTM A325, and shall have a Class 2B thread fit.

2. As part of the insert, there shall be a feature to prevent rotation of the insert after the concrete has reached its design strength.

3. The anchor insert shall have a minimum length of 3-1/2-inches and a maximum length of 3-3/4-inches allowing for a minimum 2-inch engaging threaded length.

4. In the installed position, the top of the anchor insert shall provide a flat surface parallel to the rail base with a minimum of 1/8-inch bearing width surrounding the anchor bolt hole.

5. Furnished with an installed plug of metal or plastic material to preclude the entrapment of moisture, concrete, or other foreign materials.
   a. Plug: Removal by socket or other common device and capable of reinsertion, and if reinserted, still preclude concrete and other foreign materials from entry.

6. Coated with a uniform epoxy resin insulating coating on exterior surfaces
   a. 100 percent dry powder epoxy resin such as Scotch Kote Brand Protective Resin No. 203, manufactured by Suppliers: the Minnesota Mining and Manufacturing Company (3M), Corvel Epoxy ECB-1363A, manufactured by the Polymer Corporation, or approved equal.
   b. Before coating, the insert shall be degreased and cleaned to white metal in accordance with SSPC SP 5.
   c. Apply coating in accordance with the coating Supplier's recommendations and the following general requirements, or an approved equal:
1) No thinner than 10 mils or thicker than 20 mils.
2) No runs, sags, or chips.
3) Thickness by a magnetic millimeters gauge at not less than two locations of the insert.
4) Tested in accordance with ASTM D2440, hardness not less than 85 or more than 90 Shore D.
5) Test coated insert for pin holes and breaks in a weak electrolytic solution:
   a) Immerse the coated insert in a weak electrolytic solution to within 1/4-inch of the top surface of inserts and contact a positive electrode with the non-coated, threaded, internal area of the insert. Place negative lead in the solution.
   b) Electrolytic solution: potable water with resistivity maintained to within 1,000 to 1,500 ohm-cm.
   c) Apply a 100-volt DC electrical current between the electrolyte and the insert.
   d) Perform the testing at the frequency required in the sequential statistical quality control plan developed by the epoxy coating applicator.
   e) Coating Acceptance Criteria: Circuit not closed when the insert is immersed in the electrolytic solution.
      i) Average defective rate: Not more than 2 percent.
      ii) Maximum defective rate: Not more than 5 percent.
      iii) Demonstrate defective rates at a 90 percent degree of confidence

2.04 RAIL FASTENING SPRING CLIPS:
   A. Spring clips shall be right-hand configuration.
   B. Lateral rail position adjustment by the hold down assembly shall not be permitted.
   C. Design shall not be dependent upon elastomer components in torsion.
   D. Installed into a fixed shoulder, integral to the fastener top plate.
   E. Installed without the use of threaded elements.
   F. No part of the clip shall protrude below the base of rail.
   G. The clip shall not have point contact. The clip shall be such that lateral rail movements within the confines of the shoulders will not produce transverse denting, carving, or scoring of the rail base. The clip shall be such that longitudinal rail slippage will not produce overstressing, ending, twisting, or other damage to the clips, and will not damage the rail.
H. Design not to permit rail hold-down assembly or the means of preventing lateral movement of the rail to make point contact against the rail. If contact is made in the static or dynamic state, allow no less than 0.125-inch in dimension and no less than 0.15 square inch in area.

2.05 SOURCE QUALITY CONTROL

A. High-Resilient Direct Fixation Fastener Testing: Qualification and production tests for each rail fastener are required. Comply with the following procedures for both qualification and production testing. Perform tests as shown in Figure 1A, herein, for qualification testing and in Figure 1B, herein, for production testing.

1. Qualification Testing: At the Contractor's expense. Prior to production, select for testing two (2) direct fixation fasteners. Test each fastener as specified in Figure 1A, herein. Should any of the fasteners fail to meet the test requirements, test two additional fasteners. In the event either of the two (2) additional fasteners fail, re-design the fastener, submit new Technical Data, and start the qualification test sequence over.

2. Production Testing: At the Contractor's expense. Select for testing two (2) HR direct fixation fasteners from each 1,000 production lot fasteners. Test each fastener as specified in Figure 1B, herein. Should any of the fasteners fail to meet the test requirements, test two (2) additional fasteners of the same type from the production lot. In the event either of the two (2) additional fasteners fails, the entire lot shall be rejected or tested and only those successfully passing all tests shall be incorporated in the finished work.

3. Not less than fifteen (15) days prior to each fastener shipments, certified statements for each elastomer batch used in the manufacture of the fasteners being delivered shall be submitted to the Resident Engineer documenting compliance of each elastomer batch with the requirements, as specified herein.

4. In addition to the qualification and production tests, components of the fasteners shall be subject to full or partial testing for compliance with the Contract Documents. The cost of additional testing of components that do not comply with these Contract Documents, shall be at no cost to Sound Transit.

5. Qualification and production testing may be performed at any testing facility in North America, including facilities at the Contractor's plant. Testing equipment shall be in good repair, of adequate capacity, and shall be verified or calibrated against certified standards that have a known traceable relationship to the National Research Council or the National Institute of Standards and Technology. Notify the Resident Engineer not less than fifteen (15) days in advance of dates scheduled for tests.

6. Previous Qualification testing reports may be submitted to the Resident Engineer. Provided these reports are for an appropriate product with five (5) years of in-service history and past acceptable test results for Sound Transit, Qualification testing may be waived. Production testing shall be performed in all cases.

7. Submit six (6) copies of the production test results to the Resident Engineer at least fifteen (15) days prior to fastener shipment.

B. Static Tests: Perform each test listed below on two (2) specimens.

1. Vertical Load Test:
a. Procedure: Apply a vertical load increasing in increments of 1,000 pounds to a maximum load of 13,000 pounds at a rate not less than 500 pounds per minute and not more than 2,000 pounds per minute. Loads shall be applied downward at the center of the rail head at the centerline of the fastener normal to the rail. For each increment of load, measure the vertical deflection of the rail head to the nearest 0.001-inch. Remove the load and measure and record the final position of the rail head. Plot the recorded values for vertical loads versus deflection on a graph, as shown in Figure 3, herein. Pre-cycle the fasteners by loading from 0 to 13,000 pounds two (2) times prior to measuring deflections.

b. Test Acceptance Criteria:

1) The load versus deflection curve shall lie within the envelope shown in Figure 3 for loads in the range from 2,000 pounds to 10,000 pounds.

2) The spring rate of the fastener (slope of the load-deflection curve) shall not be less than 40,800 pounds per inch or more than 61,200 pounds per inch for loads between 2,000 pounds and 10,000 pounds.
   a) Calculate the spring rate by applying the least-squares linear regression method to the recorded data to obtain a straight line load-deflection relationship.
   b) Each recorded deflection shall be within 10 percent of the deflection calculated from the straight-line relationship over the loading range, from 2,000 pounds to 10,000 pounds.
   c) After removal of the maximum load, the fastener shall return to within 0.005-inch of its original position within 1 minute.

3) At no time during the test shall any fastener component exhibit any sign of failure by slippage, yielding, or fracture. Slippage is defined to mean any movement of the fastener components relative to the initial position not attributed to deflection or yielding. The deflection measured at 10,000 pounds divided by the design thickness of the elastomer component shall be used to establish the fastener’s compliance with the requirement for a maximum vertical deflection not to exceed 25 percent of the elastomer thickness. The values obtained when this test is repeated on all fasteners shall be within 20 percent of the initial test values.

2. Lateral Load Test:

a. Procedure: While applying a vertical load of 13,000 pounds downward, offset 3/4-inch from the center of the rail head towards the gauge side at the centerline of the fastener normal to the rail, apply a lateral load horizontally to the rail at a point 3-inches above the base of rail along the centerline of each fastener normal to the rail. Apply a lateral load horizontally to the rail head at a point 0.625-inch below the top of the rail along the centerline of the fastener in a direction normal to the rail. Increase the load in increments of 1,000 pounds to a maximum load of 8,000 pounds, at a rate of not less than 500 pounds per minute and not...
more than 1,500 pounds per minute. For each load increment, measure the lateral deflection of the rail head at a point 0.625-inch below the top of the rail to the nearest 0.001-inch and record.

b. Remove the lateral load and measure and record the final position of the rail head. Plot the recorded values for lateral loads versus deflection on a graph similar to Figure 3, herein.

c. Test Acceptance Criteria:

1) The lateral deflection of the rail head for a lateral load of 4,000 pounds shall not exceed 0.15-inch.

2) The lateral deflection due to the maximum load shall not exceed 0.37-inch.

3) Difference between the original and final positions of the rail head shall not exceed 0.062-inch.

4) No fastener component at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture.

3. Longitudinal Restraint Test:

a. Procedure: Support the rail end on a roller or other low friction support properly elevated to prevent the longitudinal load from binding the rail in the fastener. Apply load longitudinally to the rail at its base increasing in increments of 500 pounds to a maximum load of 8,000 pounds or until the rail is 2-inches from the initial position at a rate not less than 500 pounds per minute and not more than 1,500 pounds per minute. Each load increment shall be maintained until the longitudinal movement of the rail stops before increasing the load to the next increment. For each load, measure the longitudinal movement of the rail in relation to the top plate of the HR direct fixation fastener to the nearest 0.01-inch and record. Remove the longitudinal load at slippage, measure and record the final position of the rail in relation to the top plate of the HR direct fixation fastener. Measure and record the load applied at slippage for use in the Push-Pull Test, as specified herein. Plot the recorded values for longitudinal load versus movement on a graph as shown in Figure 3 and identify it as “Initial Test.” Without altering test set-up, the load shall then be applied to the opposite end of the test rail and the test re-run in its entirety. Plot the recorded values for longitudinal load versus movement on a graph as shown in Figure 3 and identify it as “Reverse Test.”

b. Test Acceptance Criteria:

1) Longitudinal load versus deflection curve, when plotted on Figure 4: entirely within the limits.

2) Difference between the original (before initial test) and final (after reverse test) position of the rail: not to exceed the total rail slippage plus 0.24-inch.

3) No fastener component at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture, except that slippage which may occur between the rail hold-down assembly and the rail.
4) Rail hold-down assembly longitudinal restraint: constant, uniform and unbroken curve which falls within the envelope shown in Figure 4 herein when plotted.

5) At least 85 percent of test results shall fall within limits.

4. Lateral Restraint Test:
   a. Procedure: Apply two (2) lateral loads, each increasing simultaneously in increments of 500 pounds to a maximum load of 2,500 pounds at the base of the rail, in the same direction, normal to the centerline of the rail and symmetrically on each side of the fastener centerline. Measure the lateral deflection of the rail at the intersection of the centerline of the fastener and the gage line of the rail to the nearest 0.001-inch and record after each increment of loading.
   
   b. Test Acceptance Criteria
      1) No fastener component at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture.
      2) Difference between the original and final positions of the gage line: not to exceed 0.062-inch.
      3) Lateral deflection of the rail, when fully loaded, shall be between 0.03-inch and 0.125-inch from the original gage line of the rail.

5. Vertical Uplift Test:
   a. Procedure: Apply and secure a vertical load to the center of the rail head at the centerline of the fastener in a direction normal to the rail, alternating continually from a vertical downward load to a vertical upward load. Increase the upper and lower peaks per cycle in increments of 200 pounds to a maximum of 3,600 pounds downward and upward. Continually measure the loads and deflections to the nearest 0.001-inch and immediately record on a load-versus-time graph and deflection-versus-time graph, respectively. Remove the load and measure and record the final position of the rail head. Apply the reaction force to the uplift load by only securing the test block on which the fastener is mounted.
   
   b. Test Acceptance Criteria:
      1) Vertical deflection of the fastener for lifting load of 2,000 pounds within 105 percent to 205 percent of the deflection for a 2,000 pound downward vertical load as determined from the vertical load test.
      2) When the vertical load is continuously varied from vertical downward loads to vertical uplift loads, the load-deflection curve shall be continuous and there shall be no other indication of backlash or freeplay at times when the load or the deflection changes direction.
      3) After removal of the maximum load, the rail shall immediately return to within 0.005-inch of its original position within 1 minute.
4) No fastener components including the fastener anchor insert to the test block at any time during the test shall exhibit any sign of failure by slippage, yielding, or fracture.

C. Electrical Tests: Perform each test listed below on two (2) specimens.

1. Voltage Withstand Test:
   a. Procedure: A complete, fully assembled fastener, configured as specified, shall have a ground plate placed below the elastomer. A DC potential of 10 kilovolts shall be applied to the rail head for 1 minute. In the event of breakdown, record the breakdown voltage.
   b. Test Acceptance Criteria: The elastomer shall complete this test with no visible damage such as splits, cracks, pinholes, or fractures. Perform all other electrical tests on the fastener.

2. Electrical Resistance Test:
   a. Procedure: Test a complete, fully assembled fastener, as specified herein, for electrical resistance. Before assembly, metal parts, anchor inserts, spring clips, elastomer surfaces, and ancillary parts associated with the fastener shall be clean and dry. Assemble the fastener with a section of 115 pound RE rail, not less than 1-foot in length. Mount the test fastener on a 1/4-inch thick metallic ground plate sized to extend 1/2-inch beyond all edges of the fastener. Use anchor insert assemblies supplied, or similar to that for use in actual field installation, to mount the fastener to the ground plate. Use the same number of bolts (or other devices) that will be used to anchor the fastener in-service. Verify that all parts that should be in electrical contact do not exhibit excessive contact resistance because of improper assembly or other causes. This shall apply, but not necessarily be limited to:
      1) Rail to rail plate interface
      2) Rail hold-down assembly (clip) and rail
      3) Anchor bolts and bottom fastener plate (if present)
      4) Anchor bolts and ground plate
   b. Dry conditions: 24 hours prior to testing, store the assembled fastener(s) in a clean, dry environment with ambient conditions of 60 degrees Fahrenheit to 80 degrees Fahrenheit and 50 to 70 percent relative humidity. Apply 100 volts (minimum) dc between the rail head and the ground plate for 3 minutes. Measure the applied voltage and resulting current flow, or directly measure the resistance with an accuracy flow, or directly measure the resistance with an accuracy of plus or minus 2 percent. Instrumentation used for direct measurement shall have a minimum 100 volt output capacity.
   c. Wet conditions: Perform this test on the same fastener(s) that passed the dry electrical resistance tests. Place the assembled fastener in a nonmetallic trough or other suitable container. Size the container such that there is a minimum of 2-inches between the sides and bottom of the fastener/ground plate assembly and the sides and bottom of the container. In the event more than one (1) fastener is placed in the same container, maintain a 2-inch clearance between the edges of the ground
plates on adjacent fasteners and the clearances cited above. Pour water into the container to a level midway up the rail web covering all surfaces of the fastener. Maintain this level of immersion for 72 hours. Ambient temperature of fastener surfaces (prior to immersion), water, and air shall be 60 to 80 degrees Fahrenheit. Relative humidity shall be 50 to 70 percent. Water resistivity shall be 1,000 to 1,500 ohm-cm (use potable water and adjust resistivity by addition of sodium chloride). Drain the water from the container to a level 1/2-inch below the ground plate. Without drying or otherwise disturbing the fastener or creating a condition that causes the fastener surfaces to dry, measure the resistance within 15 seconds after draining as follows:

1) Apply 100 volts between the rail head and the ground plate for 15 seconds.

2) Measure the applied voltage and resulting current flow with an accuracy of plus or minus 2 percent. Calculate the DC wet resistance, or directly measure the resistance with an accuracy of plus or minus 2 percent. Ensure instrumentation used for direct measurement have a minimum 100 volt measuring capability.

3) Repeat the resistance measurement every 5 minutes for the first hour, every 10 minutes for the second hour, and every 15 minutes thereafter to establish the wet resistance versus time characteristics of the fastener. Perform tests for at least 2 hours after draining. The tests may be terminated after the 2-hour test period when any three (3) consecutive measurements are at least 800,000 ohms or after another 2-hour test period, whichever comes first.

d. Test Acceptance Criteria:

1) Dry conditions: The minimum DC resistance shall be 10 megarms.

2) Wet conditions: A minimum resistance of 800,000 ohms for the average of three (3) consecutive readings within 2 hours after wetting.

   a) Average difference between each of the three (3) readings: not exceed 10 percent of the average.

3. Electrical Impedance Tests:

   a. Procedure: Test one (1) complete, fully assembled fastener for electrical impedance. Apply a potential of 50 volts AC RMS to the rail head for 3 minutes for each increment of measurement for frequencies from 10 hertz to 10 kilohertz in increments of 20 hertz up to 100 hertz, 200 hertz up to 1,000 hertz, and 2,000 hertz up to 10 kilohertz. Measure the impedance after 3 minutes with an accuracy of plus or minus 2 percent and record each frequency. Upon approval by the Resident Engineer, electrical resistance may be calculated by measuring current flow, and impedance may be calculated from the measurements of resistance and capacitance using the impedance equation which applies to a resistance and capacitance in parallel.
b. **Test Acceptance Criteria:** The minimum impedance for any frequency between 20 hertz and 10 kilohertz with 50 volts AC RMS shall be 10,000 ohms.

D. **Dynamic Tests:** Perform each test listed below on two (2) specimens.

1. **Dynamic to Static Stiffness Ratio Test:**
   a. **Procedure:** Apply vertical (compression) load to the rail head over the centerline of the fully assembled fastener. The load shall be of sinusoidal waveform over a range from 3,000 pounds to 7,000 pounds and shall be applied at a rate of 10 to 20 cycles per second. After a minimum of 1,000 cycles, measure and record the dynamic deflection of the fastener at 3,000 pounds and 7,000 pounds. Immediately after completing the dynamic deflection measurements, but only after the fastener deflection has stabilized, measure the static deflection at compression loads from 3,000 pounds to 7,000 pounds in 1,000 pound increments at a rate not exceeding 1,000 pounds per minute. Measure the deflections shall be measured within an accuracy of 0.001-inch.

   b. **Test Acceptance Criteria:**
      1) Dynamic stiffness: Calculated by dividing the difference between the recorded maximum and minimum load value (the dynamic load) by the difference between the recorded maximum and minimum deflection (the dynamic deflection).
      2) The Static stiffness: Calculated by applying the least-squares linear regression method to the recorded data to obtain a straight line and determining the slope of the static load-deflection curve.
      3) The ratio shall not exceed 1.35.

2. **Vertical and Lateral Repeated Load Test:**
   a. **Procedure:** Apply loads to the rail head in such a manner as to produce a vertical downward load of 8,250 pounds, and lateral loads along the centerline of the fastener normal to the rail of 3,900 pounds to the gauge side of the rail head and 2,700 pounds to the field side of the rail head. Apply the vertical load to the rail head and the lateral loads shall be applied 3-inches above the base of rail along the centerline of each fastener normal to the rail. Alternate application of the lateral loads, each combined with alternating application and release of the vertical load, for a total of 3,000,000 complete cycles for qualification testing or a total of 500,000 cycles for production testing. Application of the field side load and vertical load and then the gauge side load and vertical load shall constitute one cycle. The frequency shall be regulated to prevent the temperature of the components from exceeding 158 degrees Fahrenheit. Do not re-torque threaded elements subsequent to the completion of the initial 500,000 cycles of loading shall not be permitted without written approval from the Resident Engineer.

   b. **Test Acceptance Criteria:**
      1) Withstand the 3,000,000 cycles for qualification testing or 500,000 cycles for production testing of load application with no evidence of failure.
2) Upon complete disassembly of the fastener and visual inspection, no fastener components shall exhibit any sign of failure by slippage, yielding, abrasion, or fracture.

3) No evidence of wear or grooving that would contribute to a failure of the rail.

4) Concrete test block at the anchor insert: no evidence of failure as a result of the dynamic test.

3. Anchor Bolt Repeat Load Test:
   a. Procedure: After completion of the Vertical and Lateral Repeated Load Test, reassemble the fastener as specified using only the original components previously subjected to testing. With the gauge side anchor bolt loosened such that a minimum gap of 1/4-inch is between the underside of the bolt head and the anchor washer, repeat the Vertical and Lateral Repeated Load Tests for 15,000 cycles.
   b. Test Acceptance Criteria:
      1) Fastener: Withstand the 15,000 cycles of loading with no evidence of failure by slippage, yielding, or fracture.
      2) Rail: No evidence of wear or grooving that would contribute to a failure of the rail.

4. Push-Pull Test:
   a. Procedure: Apply a cycling longitudinal load as close to the base of the rail as possible to slip the rail plus and minus 3/4-inch from the initial position of the fastener and relative to the fastener position, for a total of 50 cycles.
   b. Immediately following this portion of the test, apply a cycling longitudinal load equal to 80 percent of the load recorded in the Longitudinal Restraint Test, as specified herein, shall be applied as in the procedure above for a total of 25,000 cycles. Do not reposition the rail hold-down assemblies at any time during this test.
   c. Test Acceptance Criteria: Withstand the 25,000 cycles of loading with no evidence of failure. Upon visual examination, no component of the fastener shall exhibit any evidence of failure by yielding, abrasion, slippage or fracture, except that slippage which may occur between the rail hold-down assembly and the rail. The rail shall exhibit no evidence of wear or grooving that would contribute to a failure of the rail.

5. Uplift Repeated Load Test:
   a. Procedure: Apply loads to the rail head of a fully assembled fastener to produce alternately a vertical downward load of 9,000 pounds and a vertical upward load of 1,000 pounds at the centerline of the fastener in a direction normal to the rail. Alternate the application of the vertical loads for a total of 1,500,000 complete cycles. Regulate the frequency to prevent component temperature from exceeding 158 degrees Fahrenheit. Do not re-torque threaded elements without written approval from the Resident Engineer. Apply the vertical loading during this part of the test at a rate of not less than 25 cycles per minute. If required for
testing stability, install a mechanical stop 1/8- inch from each end of the rail, independent of the test rail fasteners.

b. Test Acceptance Criteria: Withstand 1,500,000 cycles of load application with no evidence of failure. Upon visual inspection, no component of the fastener shall exhibit any evidence of failure by yielding, abrasion, or fracture. The rail shall exhibit no evidence of wear or grooving that would contribute to the failure of the rail.

6. Dynamic Longitudinal Restraint Test:

a. Procedure: The dynamic longitudinal restraint test procedure is the same as for the static test specified herein, with an additional vibration load applied vertically to the rail head while the longitudinal load is applied. Vertical vibration load: 50 hertz cyclic load with amplitude of 2,000 pounds. Apply vertical load at the rail head at the mid-point between rail seats.

b. Test Acceptance Criteria:

1) Longitudinal load versus deflection plot is linear within the limits shown in Figure 3, herein. At no time during the test shall any component exhibit evidence of failure including permanent deformation.

E. Anchor Insert Tests:

1. General:

a. Anchor inserts used for testing shall conform to the design submitted by the Contractor and approved by the Resident Engineer.

b. Production anchor inserts shall be used for tests unless prototype model testing is approved in writing by the Resident Engineer. Before Resident Engineer approval, the Contractor shall submit data showing that the prototype will react in the tests as would the production models. Should prototype testing qualify the anchor insert design, four (4) production models shall be tested immediately after production is started. Should a production model fail the test, the entire anchor insert test series shall be repeated using production models. Such tests shall be done at the same laboratory as the earlier tests.

2. Test Conditions: Fourteen (14) test anchor inserts for each anchor shall be furnished by the Contractor. Seven (7) assemblies shall be retained by the Resident Engineer and the other seven (7) assemblies shall be numbered one through seven. Anchor inserts two through seven shall be tested in cast concrete plinth as shown on the Contract Drawings, utilizing the minimum plinth dimensions and specified reinforcement. Concrete shall have a compressive strength in accordance with cast-in-place concrete requirements as stated elsewhere in the Contract Documents, and this shall be verified by laboratory tests. Anchor inserts shall be placed in the concrete plinth in accordance with the Contract Drawings.

3. Static Load Tests:

a. Thread Failure Test (Anchor Insert Number 1):

1) Procedure: Anchor insert shall be held in a vise or other device and the bolt twisted to failure. To prevent bottoming before
failure, the bolt shall be fitted with a spacer, cut washers, or other means. To provide minimum thread contact only, the spacer thickness shall be designed such that the minimum thread is engaged.

2) Test Acceptance Criteria: Anchor insert shall withstand 600 foot-pounds of torque without evidence of failure. After removal of the torque, the bolt shall be removed from the insert with a torque no greater than 600 foot-pounds. When torqued to failure, the failure shall be in the bolt threads, not the insert threads.

b. Torsion Test (Anchor Inserts Numbers 2 and 3):

1) Procedure: Anchor insert shall be subjected to a 600 foot-pound of torque applied to the cap bolt head with spacers used on the bolt to prevent bottoming.

2) Test Acceptance Criteria: Anchor insert shall not rotate and concrete shall not crack or show evidence of failure.

c. Restrained Pull-Out Test (Anchor Inserts Numbers 4 and 5):

1) Procedure: A steel plate with a hole in the center 1/2-inch in diameter larger than the maximum diameter of the top of the insert shall be placed over the anchor insert on the concrete test block surfaces. The anchor bolt shall then have an upward vertical load of 20,000 pounds applied, held for a minimum of 1 minute, and then released.

2) Test Acceptance Criteria: Anchor insert shall have no evidence of failure from causes including but not limited to, slippage and cracking of the concrete at the indicated load.

d. Unrestrained Pull-Out Test (Anchor Inserts Numbers 6 and 7):

1) Procedure: The anchor insert shall have an upward vertical load applied in such a manner that no vertical load is applied to the concrete test block surface within a radius of six inches from the center of the insert. An upward vertical load of 10,000 pounds shall be applied and held for not less than 1 minute.

2) Test Acceptance Criteria: There shall be no evidence of failure from causes including, but not limited to, slippage, and cracking of the concrete to assembly bond at the specified loads.

2.06 FIGURES

A. Figure 1A – Qualification Tests

B. Figure 1B – Production Tests

C. Figure 2 – Vertical Deflection Limits

D. Figure 3 – Longitudinal Restraint Test Plot
PART 3 - EXECUTION

3.01 INSTALLATION

A. HR direct fixation fasteners shall be installed in accordance with track construction requirements as stated elsewhere in the Contract Documents.

END OF SECTION
## QUALIFICATION TESTS (QT)

### STATIC TESTS (ST)

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<th>Test Name/Abbr.</th>
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### ELECTRICAL TESTS (ET)

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NOTES:

1. MAXIMUM DEFLECTION AT 10,000 LBS. SHALL NOT EXCEED 25% OF THE UNCOMPRESSED THICKNESS OF ELASTOMER PAD.

2. FASTENER SPRING RATE MUST BE BETWEEN 40,800 LBS./IN. AND 61,200 LBS./IN. FOR ALL LOADS BETWEEN 2,000 LBS. AND 10,000 LBS.
SECTION 31 11 36.14 – FIGURE 3

LONGITUDINAL RESTRAINT TEST PLOT

END OF FIGURES
PART 1 - GENERAL

1.01 SUMMARY:

A. This Section includes requirements for the construction of concrete crossings as indicated on the Contract Documents. Roadway and pedestrian crossing construction includes selecting and qualifying of crossing types, and installation of crossings.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.

1. ASTM International (ASTM)
   a. ASTM D257 Standard Test Methods for DC Resistance or Conductance of Insulating Materials

1.03 SUBMITTALS

A. Detailed description of construction procedures for installing each type of grade crossing shall be installed in the Work.

B. Technical Data for the Work as specified herein.

1. For each type of crossing system submit the Supplier’s Technical Data.

C. Electrical Isolation Test Report.

1.04 QUALITY ASSURANCE

A. Manufacturers:

1. Crossing Manufacturers are required to have five (5) years of crossing in-service performance history and components of crossing systems fabricated by a recognized manufacturer regularly engaged in the production of specified items. History shall be for light rail application and include electrical isolation performance.

PART 2 - PRODUCTS

2.01 CROSSINGS

A. General:

1. Included crossing systems are for at-grade modular segment type roadway and pedestrian crossing system.

B. Used within ballasted and direct fixation track implementing a direct fixation fastener, as specified in the Contract Documents.
C. Material Composition: insulator type design to retard stray current, providing volume bulk resistivity of $1 \times 10^{7}$ ohm-cm according to ASTM D257.

D. Provided with a proven marking paint, when required, to delineate limits of pedestrian crossing.

2.02 DIRECT FIXATION TRACK PEDESTRIAN CROSSING PANELS, CONCRETE:

A. Furnish precast concrete panels materials for ballast and direct fixation track pedestrian crossings made up of two modular panel center sections and two field section concrete blocks.

B. The following crossing types are examples of acceptable pedestrian crossings:

1. Omega Industries
   7304 NE St. Johns Road
   Vancouver, WA 98665
   OMNI Grade Crossing Systems
   2075 N. Preakness Drive
   Nixa, MO 65714

2. Approved equal

C. Durable and capable of routinely handling incidental loading from passing hy-rail vehicle tires overlapping rail head.

2.03 ROADWAY CROSSING PANELS, CONCRETE:

A. Furnish precast concrete panels materials for ballast and direct fixation track roadway crossings as required by the Contract Documents.

B. The following crossing types are examples of acceptable crossings:

1. Omega Industries
   7304 NE St. Johns Road
   Vancouver, WA 98665
   Oldcastle Precast
   2808 ‘A’ Street SE
   Auburn, WA 98002
   OMNI Grade Crossing Systems
   2075 N. Preakness Drive
   Nixa, MO 65714

2. Approved equal

2.04 CROSSING CONFIGURATION

A. Crossing Surfaces:

1. Prefabricated modular panels without modifications to the Manufacturer's standard design except those approved.

2. Removable panels: allow uncomplicated removal and re-installation without causing damage to the crossing system.
3. Full installation: Not to require new material after removal and when being re-installed.

4. Skid resistant surface: Proven effective, and highly resistant to chemicals and organic solvents.

B. Crossing panels:
   1. Fit without field modifications.
   2. Four piece or less modular section without shims to support the panels.
   3. Contoured to suit the top of concrete profile providing required clearance for fastening clips.
   4. Designed to seat on the entire plinth surface providing full bearing support except in the fastening area.

C. Crossing Components:
   1. Supply each crossing with associated standard hardware necessary for a complete installation including:
      a. The crossing surface and, if applicable, other fastenings necessary for attaching the crossing surface to concrete plinths.
      b. Tapered modular pieces or other approved means to close each end of the crossing to prevent damage from dragging equipment.
      c. Manufactured hardware to attach end modules to the crossing system and concrete invert.
      d. Special tools, if any, for handling and installing of crossing panels.
      e. Track Gauge: 4-feet and 8-1/2-inches, measured between the inside faces of the running rail at a point 5/8-inch below the plane defined by the top of the two rails.
      f. Flangeway:
   2. Ensure that the crossing system has no rail-to-ground connection or rail-to-rail connection that will cause grounding of the rail or shunting the signal circuit.

D. Special Tools (If required to install the crossings): Furnish two (2) sets to the Resident Engineer following Work for future use by Sound Transit.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install the crossing in accordance with the Supplier’s instructions and the approved construction procedures.
B. Construct concrete panel support blocks adjacent to plinths as shown on the Contract Drawings.

C. Space concrete ties in accordance with the requirements specified by the crossing manufacturer.

D. Install standard rail anchors on each at end of crossing panel as shown on the contract drawings.

E. Determine electrical isolation from the rail to concrete crossing panel for each rail on the gauge and field side (one measurement per track per grade crossing).
   1. Minimum impedance required: 10,000 ohms at 50 volts AC between a frequency range from 20 Hz to 20,000 Hz.

F. Apply crossing paint markings in conformance with the Contract Drawings.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:

1. The removal, refurbishing and re-installation of existing Bumping Posts as noted elsewhere on the Contract Documents.

2. The design, furnishing and installation of Bumping Posts as noted elsewhere on the Contract Documents.

1.02 SUBMITTALS

A. Work Plan for removing, refurbishing and installing Bumping Post.

B. Shop Drawings of Bumping Post

C. Work Plan for Installing Bumping Post.

PART 2 - PRODUCTS

2.01 LRV BUMPING POST

A. Bumping post shall be a sliding type friction element buffer stop, clamped to the rail, such as Rawie 12 EB, or approved equal.

B. Complete assemblies including a steel bumping post equipped with a sliding friction buffer stop and suitable for anticlimber impact.

C. Bumping posts shall be designed to bring an AW0 loaded LRT four-car train under specified speed to a full stop within specified distance without damaging the light rail vehicles (train) or injuries to operators.

D. Bumping posts shall be designed to dissipate kinetic energy created by stopping four-vehicle train with vehicle weight loading (AW0) of 110,000 pounds for each vehicle, and design impact speed of 10 miles per hour. Refer to Contract Drawings for design gradient of track through the slide area.

E. Bumping posts shall be designed to slide less than or equal to 18 feet after impact at a deceleration rate of 0.30g or less to safely absorb the amount of kinetic energy without damaging the light rail vehicle (train) or injuries to operators.

F. Buffer post maximum reaction force during impact: No more than the 100,000 pounds maximum reaction force that the light rail vehicle’s anti-climber can withstand without damage.

G. Contain a stopping distance safety factor of 1.0.

H. Track gauge: 4 feet 8-1/2 inches.
I. Symmetrical about the centerline of the track.

J. Support members shall not project below the rail.

K. Design to engage the anti-climber of the LRT vehicle and prevent any member from obstructing the coupler from the retracted position to the open position. Upon request, Vehicle Drawings will be supplied by Sound Transit to provide information on the following:

1. Coupler location and clearance from top of rail.
2. Width of coupler shall be cleared.
3. Coupler maximum swing angle from center of vehicle.
5. Vehicle anti-climber horizontal curvature.
6. Bottom clearance of the anti-climber to top of rail.
7. Center distances of the anti-climber’s brace supports.

PART 3 - EXECUTION

3.01 BUMPING POST RELOCATION

A. Stationing on the Contract Drawings indicates the front of the cushion head of the bumping post.

B. Remove bumping posts at the locations indicated on the Contract Drawings and in conformance with the manufacturer’s recommended procedures. Salvage bumping post as part of demolition – general and structure as stated elsewhere in the Contract Documents.

C. Bumping posts shall be reconditioned as may be required prior to installation. Rehabilitation shall include disassembly, cleaning, painting, lubrication and certification. Threaded fasteners shall be replaced with new fasteners, of like size and grade.

D. Install bumping posts at the locations indicated on the Contract Drawings and in conformance with the manufacturer’s recommended procedures.

3.02 BUMPING POST INSTALLATION

A. Stationing on the Contract Drawings indicates the front of the cushion head of the bumping post.

B. Install bumping posts at the locations indicated on the Contract Drawings and in conformance with the manufacturer’s recommended procedures.
PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
   1. Designing and providing the Traction Electrification System (TES) Work generally includes providing new traction power facilities, including the following:
      a. Traction Power Substations.
      b. Positive DC feeder cables from the substations, disconnecting switches and tie breakers to the OCS.
      c. Negative feeders from the substations to the running rails or the impedance bonds.
      d. Traction power system transfer trip cable tie-in Work from existing ST TPSS’s.
      e. Interface with SCADA, associated systems and communication systems.

1.02 REFERENCES
A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:
   1. American Welding Society (AWS):
   2. ASME International (ASME):
      a. ASME BPVC IX - Boiler and Pressure Vessel Code, Section IX: Welding, Brazing, and Fusing Qualifications.
   3. National Electrical Manufacturers Association (NEMA):
      a. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum).
   4. Society for Protective Coatings (SSPC):
      a. SSPC Paint 16 - Coal Tar Epoxy-Polyamide Black (or Dark Red).

1.03 SUBMITTALS
A. Shop Drawings Format:
1. Use the Sound Transit Link Light Rail Equipment and Facilities Numbering Plan on submitted Contractor drawings and submittals.

2. Provide a number for each major piece of equipment such as switchgear sections, circuit breakers, and devices.
   a. Prefix: Traction power substation number or OCS segment, as indicated on the Contract Drawings.
   b. Suffix: Indicates the type of equipment or device.

3. Resident Engineer will furnish numbering scheme


5. Identification Scheme: Provide for wires and cables common to both substation and OCS schematics.

B. Provide each of the drawing types listed below for traction power substations:

1. One-line Diagrams: Provide for the system, and for each substation.

2. Three-Line Diagrams: Provide for each substation.

3. Schematic Diagrams:
   a. Format by subsystem, using identical device symbols and wire designators for each subsystem.
   b. Clearly delineate interfaces, from page to page and subsystem to subsystem.
   c. These drawings shall include at least the following information:
      1) Substation connection and interconnection electrical schematic drawings shall indicate all wire connections, terminations and identification and shall show nominal voltages, equipment and equipment ratings, currents, frequencies, significant resistance values, and the rating of all loads.
      2) Schematic location (page number, for example) of the energization portion of each device (such as the coil in a relay) shall be noted adjacent to the operating portions (such as relay interlocks) of the device.

4. Wiring Diagrams:
   a. Provide a set of wiring diagrams for each substation.
   b. Show all wiring, raceways, conduits, and connections.
   c. Provide equipment connection, intra-cubicle, and inter-cubicle wiring diagrams:
      1) Connection diagrams shall show the internal wiring and terminal block arrangement within each piece of equipment and shall identify each outgoing power and control connection and wire.
2) Interconnection diagrams shall show wiring from the equipment terminal blocks, to external equipment connections, terminal blocks, and devices.

3) Show nominal voltages, equipment and equipment ratings, currents, frequencies, significant resistance values, and the rating of all loads.

4) Label devices identical to the actual device and show their locations on panels.

5) Each terminal block and device shall have its own unique numbers and letters for identification.

d. As a minimum, provide the following information for each wire segment:

1) Wire code (schematic designation).

2) Origin (FROM device and terminal).

3) Destination (TO device and terminal).

4) Wire size.

5. Substation Equipment and Raceway Drawings:

a. Equipment arrangement drawings: Show actual equipment to be provided and details of installation, using the layout provided in Contract Drawings.

b. Alternate substation equipment layouts may be proposed by Contractor, subject to Resident Engineer’s approval.

c. Provide the following drawings as a minimum:

1) Substation plans and elevations showing the equipment layout, including equipment numbers, locations, and dimensions.

2) Equipment front elevations and wall elevations showing the location of each piece of equipment and dimensions.

3) Detail drawings of the substation local centralized monitoring system, showing devices, nameplates, front panel elevations, and details.

4) Installation and mounting details for all equipment, including installation of the transformer enclosure partitions, method of anchorage for each piece of equipment, and method for providing electrical isolation for the dc switchgear.

5) Raceway layout plans showing cable trays, conduits, including numbers, locations, and dimensions.

C. Substation ANSI Device Table:

1. Provide a set of device tables for substation ANSI devices in a single section at the rear of the schematic diagrams submittal.

2. Arrange the table in a logical fashion by system device type.
3. Provide data for all system and subsystem components including, but not limited to:
   a. Electrical control and power components (groups, panels, pc cards, contactors, relays, circuit breakers, capacitors, inductors, resistors, specialized modules, rectifiers, diodes, fuses and other components, as appropriate).
   b. Electrical equipment (rectifiers, transformers, switchgear, substation local centralized monitoring system, interface terminal board, and the like).
   c. Include the following data:
      1) Equipment and associated number where a device is located.
      2) Elementary schematic drawing number where the device appears.
      3) A brief description of the device.
      4) Manufacturer's model or style number.
      5) Manufacturer's name and type number of the device.
      6) Device rating.
      7) Number, rating and types of contacts on device, if applicable.
      8) Remarks on any other relevant features of the device.

D. Bills of Material (BOM):
   1. Final Copies of Bills of Materials: Submit before installation of the first material.
   2. Revisions: Submit after approval of a modification requiring revision.
   3. Include the following information for BOM:
      a. Contractor number.
      b. Supplier number.
      c. Provision for Sound Transit's storage number.
      d. Other data required for procurement of materials used in the construction of all parts of the electrification system.
      e. Cross-reference to related drawings and the BOMs.
      f. Generic description or specification.
      g. Brand name, where applicable.
      h. Manufacturer's part number.
      i. Original manufacturer or supplier, including address, telephone number, internet address, FAX number, and contact person.
      j. Notation on parts that are custom manufactured only upon request.

E. Closeout Submittals:
F. Provide complete, individual as-built drawing sets for each TPSS including all drawing types listed above, in compliance with Section 01 78 39, As-Built Documents.

1.04 QUALITY ASSURANCE

A. Installer Qualifications: Work specified in this Section shall be performed by Washington State unlimited licensed electricians working for an Electrical Contractor licensed by the State of Washington, skilled and experienced in the installation of the particular products specified in this Section, except as follows:

1. Welding shall be done by qualified, certified welders who make only those welds for which they have been qualified in accordance with AWS D1.1/D1.1M, ASME BPVC, Section IX, or other approved qualifying procedures.

2. Records of welder qualification tests shall be made available for review upon Resident Engineer’s request.

3. The electrically insulated floor covering shall be installed by approved workers skilled and experienced in the installation of the product.

PART 2 - PRODUCTS

2.01 TRACTION ELECTRIFICATION SYSTEM DESCRIPTION AND DESIGN CRITERIA

A. Traction Electrification System General Parameters:

1. New prefabricated TPSSs shall be furnished and installed in locations shown on the Contract Drawings.

2. Positive dc feeder cables from the substations, disconnecting switches and tie breakers to the OCS shall be furnished and installed.

3. Negative dc feeders from the substations to the running rails or the impedance bonds shall be furnished and installed.

4. Traction power system transfer trip cable tie-in Work from existing ST TPSS’s shall be furnished and installed.

5. Interface with SCADA, associated systems and communication systems shall be furnished and installed.

6. Substation Rating: 3 Megawatts or as shown on Contract Drawings, extra heavy duty traction service.

7. Substations will be unattended.

8. Dc System Voltage:
   a. 1590 Vdc at 1 percent load.
   b. 1500 Vdc at rated load.


10. Substations will be controlled and monitored by local centralized monitoring system (LCMS) and supervisory control and data acquisition system (SCADA). Three control levels shall be provided.
a. Equipment Level: When "Local" is selected, the switchgear operation is controlled locally only. Neither LCC (Link Control Center) level nor LCMS level is able to send control command to the switchgear.

b. LCMS Level: When "Local" is selected, switchgear is controlled from the LCMS HMI only.

c. LCC Level: Operation command of switchgear from LCC is possible only when both equipment level and LCMS level have been set to “Remote”.

B. Equipment Environmental Requirements:

1. Provide substation equipment suitable for operation at its specified ratings under the specified conditions and operation, without impairments, throughout the range of values listed below.

2. Temperature:
   b. 24 Hour Average Ambient outdoor Temperature: 30 degrees C. (86 deg F).
   c. Minimum Ambient Outdoor Temperature: Minus 18 degrees C. (0 degree F).
   d. Maximum Ambient Outdoor Humidity: 90 percent.


4. Seismic: In accordance with Section 26 05 00, Common Work Results for Electrical. Meet seismic requirements specified in the International Building Code (IBC) as adopted by Authority having Jurisdiction (AHJ). Provide suitable bracing and anchorage and submit calculations performed and sealed by a structural engineer registered in Washington.

5. Altitude: Less than 500 feet above sea level.

2.02 PERFORMANCE

A. Regulatory Requirements:

1. Comply with current federal, state and local requirements including but not limited to applicable Local Authority Having Jurisdiction (AHJ), local Fire Department and Washington State Department of Labor and Industries (L&I).

B. Performance Requirements - General:

1. Provide electrification equipment proven in similar railroad, rail transit, or heavy industrial service.

2. Each component, subassembly and assembly provided in this Contract shall be of a proven design with a history of at least 5 years successful operation at the time of Contract award in similar railroad or rail transit service.

3. Systems Integration: Integrate TES elements, such that specified requirements are achieved without conflict or error within or between specified elements, and between the TES and other Systems and Civil components, including interface with existing TES systems.
4. **Life Cycle Requirements:**
   a. Traction Electrification System Expected Service Life: 30 years in continuous service, 24 hours a day, 365 days a year.
   b. Use off-the-shelf service-proven equipment and hardware to achieve this useful life.
   c. Provide replacement spare parts that are functionally and physically interchangeable for each product class.

2.03 **MATERIALS**

A. **Materials and Equipment:**
   1. Material shall be new and suitable for the use intended and of the manufacturer’s latest standard design.
   2. Materials and equipment provided shall fit within the space provided and shown on the Contract Drawings.
   3. Provide materials and equipment which are standard products of manufacturers regularly engaged in the production of such material and equipment.
   4. Where two or more units of the same class of material or equipment are required, provide products of a single manufacturer.
   5. Similar component parts of different larger assemblies are not required to be the products of the same manufacturer.
   6. Discontinued materials or products shall not be permitted.
   7. Each type of material and equipment shall be of the same manufacture and quality throughout the work.

B. **Listed and Labeled Equipment and Material:**
   1. Provide wherever standards for these products have been established.
   2. Materials that are not listed or labeled require approval by Sound Transit prior to use.
   3. Products which have not been tested or certified for the use intended shall not be used when equivalent listed or labeled materials are available.
   4. The label or listing will be acceptable as sufficient evidence that the materials and equipment do conform to the specified standards.
   5. Electrical equipment and material not listed or labeled shall be furnished with a Field Evaluation label provided by a Testing Laboratory approved by the Washington State Department of Labor and Industries (L&I), and certifying that the equipment conforms to the requirements of UL and IEEE or ANSI.
   6. This product evaluation may be performed in the factory or on-site as approved by L&I.
   7. A request for permission to perform a Field Evaluation in the factory or onsite shall be submitted to L&I for approval.
C. Material and equipment shall be designed to ensure satisfactory operation and life in the environmental conditions that exist where the material or equipment is installed.

D. Provide material and equipment suitable for its intended environment as defined by National Electrical Code (NFPA 70):
   1. Wet Locations: Refer to Section 26 05 33, Raceways and Boxes, 3.07 B, Box Type Requirements.
   2. Damp Locations: Refer to Section 26 05 33, Raceways and Boxes, 3.07 B, Box Type Requirements.
   3. Wet or Damp Locations: Provide corrosion resistant fittings or supports, hot-dip galvanized or as otherwise specified.
   4. Dry Locations: Corrosion resistant painted finishes may be used for equipment and enclosures as approved by Sound Transit.

E. Dissimilar Material Connections:
   1. Not permitted at electrical connections or connections requiring disassembly for maintenance or for removal and replacement of equipment.
   2. Not permitted except at permanent connections.
   3. Provide suitable electrochemical isolation.
   4. Isolation treatments shall be permanent and not require maintenance or replacement for the life of the equipment or installation.

F. Ferrous Metal:
   1. Above Grade: Refer to individual technical sections for requirements.
   2. Below Grade and Not Concrete Encased: Hot-dip galvanized and coated with minimum of two coats of coal tar epoxy applied to 8mils dry film thickness per coat, except as otherwise specified for PVC coated GRS conduit.

G. Galvanizing:
   1. Wherever “galvanized” is called out in Traction Power application, the material shall be “hot-dip galvanized” and coated in accordance with Section 34 21 27 Metal Fabrication and Finishes.
   2. Wherever materials are called out as “hot-dip galvanized” or “galvanized”, the coating is intended to be applied in addition to normal manufacturer’s finish.
   3. Materials or products specified which are not readily available in the specified hot-dip finish, shall be “custom” hot-dip galvanized after manufacture by an independent galvanizer.
   4. Where finishes are called out as galvanized and the specified product cannot be either manufactured with a hot-dip finish, or cannot be hot-dip galvanized after manufacture, the specified product shall be furnished with a finish that will perform equal to hot-dip galvanizing as approved by Sound Transit.
PART 3 - EXECUTION (NOT USED)

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:
   3. Other test requirements that appear in other Sections.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. Institute of Electrical and Electronics Engineers (IEEE):
   d. IEEE 1106 - Recommended Practice for Installation, Maintenance, Testing, and Replacement of Vented Ni-Cad Batteries for Stationary Application.
   e. IEEE 1653.2 - Standard for Uncontrolled Traction Power Rectifiers for Substation Applications Up to 1500 VDC Nominal Output.
   g. IEEE C37.20.1 - Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear.
   h. IEEE C37.30.1 - Standard Requirements for AC High-Voltage Air Switches Rated Above 1000 V.
   i. IEEE C37.41 - Standard Design Tests for High-Voltage (>1000 V) Fuse and Disconnecting Cutouts, Distribution Enclosed Single-Pole Air Switches, Fuse Disconnecting Switches, and Fuse Links and Accessories Used with These Devices.
1. **IEEE C57.12.91 Standard Test Code for Dry-Type Distribution and Power Transformers.**

2. **IEEE C57.13 - Standard Requirements for Instrument Transformers.**

2. **National Electrical Manufacturers Association (NEMA):**
   - a. **NEMA PE5 - Utility Type Battery Chargers.**

3. **International Electrical Testing Association (NETA):**
   - a. **NETA ATS - Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems.**

### 1.03 SUBMITTALS

**A. Test Program Plan:**

1. **Test Procedures:**
   - a. Submit for each test to be performed under the appropriate Technical Section of these Specifications, not under this Section.
   - b. Tests shall not be performed and test reports will not be considered valid until procedures are approved by Resident Engineer.

2. **Test Results:**
   - a. Submit test data after test is performed.
   - b. Submit for each test to be performed under the appropriate Technical Section of these Specifications and under this Section.

3. **Test Reports:**
   - a. Submit after completion of each test unless otherwise indicated.
   - b. Submit for each test performed under the appropriate Technical Section of these Specifications and under this Section.
   - c. **Factory Design Test Reports:**
     1) Submit existing test reports prior to scheduled shipment of equipment. Do not ship the equipment until the report is approved by the Resident Engineer.
     2) Submit graphical test results including time current characteristic curves for Frame Fault Relay (Device 64 G and H) after completion of the test.
   - d. **Factory Production Test Reports indicated in this Section.**
   - e. Submit Electrically Insulated Floor and Wall Test Report for each substation prior to installation of substation equipment.
   - f. **Submit the following test reports prior to TPSS Site Acceptance Testing:**
2) Substation Ground Test Report. Provide a plot of ground resistance readings on 8.5 by 11-inch size graph paper.

g. Traction Power Substation Site Acceptance Test Reports.

h. Integrated Testing Test Reports:
   1) SCADA Tests.
   2) Rail Voltage Monitoring and Grounding Devices Tests.
   3) Train Start Tests.

4. Qualifications Statements: For testing agency.

5. Test Equipment:
   b. List of proposed test instruments and equipment.

1.04 QUALITY ASSURANCE

A. Testing Agency Qualifications: Tests shall be performed by the manufacturer, or a company or agency employed by Contractor with all of the following qualifications:

1. Approved by Resident Engineer. Once such a company or agency is approved they shall not be discharged or otherwise replaced by Contractor without written approval of Resident Engineer.

2. Personnel assigned to the project shall be familiar with electrical/electromagnetic testing procedures, electrical/electromagnetic instrumentation, and general electrical networks.

3. Personnel shall be capable of modifying the specified procedures to suit actual field conditions should such modifications become necessary.

B. Witnessing of Tests:

1. Resident Engineer will, at his/her option, witness all tests.

2. Testing Notification: At least 30 Days prior to each test upon the approval of test procedure, notify Resident Engineer in writing of the date, time, and location the test will be performed.

3. If Resident Engineer elects not to witness a test or tests, test reports shall nevertheless be submitted to Sound Transit for review and approval.

4. Witnessing of test by Resident Engineer shall not relieve Contractor from its responsibility to produce test report in accordance with Contract Documents.

C. Performance of Testing:

1. Testing shall be performed under the direct supervision of the manufacturer of the equipment, except that:
a. Factory design test or production test of individual components shall be performed by the component manufacturer at the plant of manufacture or at an approved testing facility.

b. Field testing of insulated power cables rated 2 kV and higher shall be performed by a NETA certified technician working for an independent testing company under the direct supervision of Contractor:
   1) NETA technician shall have at least 5 years’ experience in construction acceptance testing.
   2) Testing company shall be a NETA member and approved by Resident Engineer.

c. Site acceptance testing of each substation shall be performed under direct supervision of Traction Power Installation Supervisor specified in Section 34 21 16.25, Traction Power Substation Installation, and the representative from the manufacturer(s) of the substation equipment.

D. Test Classifications:

1. Factory Design Tests (Level 1 Tests):
   a. Shall be conducted by or under supervision of the equipment manufacturer.
   b. Shall demonstrate compliance with specified design requirements.
   c. Shall be performed on production components, assemblies, subsystems and substations and shall be performed on the highest level of assembly that will allow demonstration of design compliance.
   d. Limited to the number of units needed to demonstrate design compliance, typically one or two.

2. Factory Production Tests (Level 1 Tests):
   a. Shall be conducted by or under the supervision of the equipment manufacturer.
   b. Shall demonstrate that unit to be delivered operates within specified limits and is in compliance with design requirements and industry standards.
   c. Test requirements may vary from an inspection and functional demonstration for a simple component to a full system functional demonstration of an assembly.
   d. Perform tests of the completed substation equipment at substation manufacturer's facility prior to shipment of the equipment to the site.
   e. Include the following:
      1) Substation/section tie breakers equipment and ancillary systems including control power for each substation.
      2) Factory installed power and control cable and wire.
f. Perform at ambient conditions unless a specific environmental or Operating limit is necessary to demonstrate acceptable operation.

3. Traction Power Substation Field Installation and System Tests (Level 2 Tests):
   a. Shall demonstrate that each substation and section tie breaker is ready for energization and revenue service, both functionally and cosmetically.
   b. Include Testing of:
      1) Substation/section tie breaker equipment.
      2) AC and DC Protective relays.
      3) Ancillary systems.
      4) Field installed power and control cable.
      5) Wiring internal and external to substations/section tie breakers.
      6) Protective devices.
   c. System Integrated Testing (Level 3 Tests):
      1) Shall demonstrate that the installed TES system functions properly in relation to other system elements.
      2) Shall demonstrate that all interfaces are correct and operable.

E. Quality of Test Data: Test Readings:
   1. Number of readings taken to determine an electrical/electromagnetic constant or property shall be sufficient to ensure that random factors due to human error in reading the instruments and transient disturbances in electrical/electromagnetic network have negligible influence on final results.
   2. Adequacy of the data can generally be established by the tester as follows:
      a. Data shall be examined to verify that removal of either the highest or lowest value will not alter the arithmetic average of the group by more than 5 percent.
      b. If the average would be altered by more than 5 percent, one more set of data shall be taken and results combined with the first set.
      c. If the average of the combined data would still be altered by more than 5 percent if the highest or lowest value were removed, an unstable condition might exist and Resident Engineer shall be advised.

PART 2 - PRODUCTS

2.01 FACTORY DESIGN TESTS

A. General:
   1. Factory design tests shall be run on each type of equipment.
2. If design tests have already been performed by the manufacturer of equipment, existing test reports may be submitted. Resident Engineer will determine whether a new design test may be waived.

3. Existing test reports need not meet the format requirements specified in this Section. However, content of reports shall include all relevant information to satisfy design standards and Specifications.

4. In the event components have not been design tested, tests shall be run on the first production unit and performed in accordance with these Specifications.

5. Sound Transit reserves the rights of requiring test report of any device provided under this contract. Failing to provide appropriate report results in rejection of the device.

B. TPSS Enclosure:

1. Rain test for TPSS enclosures: Perform in accordance with IEEE C37.20.1. An existing design test will not be accepted; this test will not be waived.
   a. In addition to IEEE C37.20.1 requirements, all HVAC systems shall be operating at full speed.
   b. Replace IEEE C37.20.1 satisfaction of test requirements with the following: the enclosure shall have satisfactorily met the requirements of this test if during the visible inspection no water is found inside the enclosure.
   c. Each TPSS enclosure with all equipment installed shall be rain tested.

C. Traction Power Transformer:

1. Resistance measurements of all windings on rated voltage connection and on all tap settings.

2. Impedance and load losses at rated current on all windings on all tap settings in accordance with IEEE 1653.2. Calculate transformer commutating reactance from these tests.

3. Short Circuit Tests:
   a. Conduct at a certified laboratory having specified power supply.
   b. Perform in accordance with IEEE C57.12.91, to fully evaluate the capability of all windings.
   c. Apply faults to terminals of each secondary winding.
   d. Make all recommended terminal measurements.

4. Impulse Tests:
   a. Perform in accordance with IEEE C57.12.91 with exception that waveform to be used shall be 1.4 by 40 microseconds.
   b. Perform after completion of short circuit tests.

6. Audible Sound Level Test: Refer to Section 34 21 16.26, Transformer-Rectifier Unit, for detailed requirements.

7. Resident Engineer shall be the sole judge of the serviceability of transformer after completion of design testing.

D. Rectifier:


2. Rated Voltage Test: Subject rectifier to 110 percent of ac rated voltage for 5 minutes with the dc circuit open.

3. Current Unbalance Test:
   a. Maximum current unbalance between rectifier legs shall not exceed plus or minus 10 percent when measured between 50 percent and 150 percent of the rated capacity.
   b. Test may be performed during the design test for transformer-rectifier unit.

4. Loss Measurement Test:
   a. Perform in accordance with IEEE 1653.2.
   b. Test for losses at overloads up to 150 percent.

5. Rated Current Test:
   a. At reduced voltage.
   b. After temperature stabilization at rated load.
   c. Include the overloads outlined in IEEE 1653.2.
   d. Perform with one diode removed from each phase arm.
   e. Shall demonstrate that the maximum safe junction temperature for each diode is not exceeded.

6. Efficiency, Voltage Regulation and Power Factor:
   a. Demonstrate for loads of 1, 25, 50, 100, 150, and 450 percent of rated load.

E. Transformer-Rectifier Unit Test:

1. Existing test reports will not be accepted in lieu of this test.

2. Transformer-rectifier unit shall be tested as a complete assembly including interconnecting bus and/or cables and enclosures. Ac and dc switchgear are not a required part of this assembly.

3. Perform rated current load tests at reduced voltage.
4. Demonstrate compliance with the requirements specified in Section 34 21 16.26, Transformer-Rectifier Unit.

5. Operate transformer rectifier at 100 percent load for a minimum of 6 hours immediately before running duty cycle tests to ensure temperature stabilization.

6. Verify efficiency, power factor and voltage regulation at loads shown in IEEE 1653.2 for Extra Heavy Traction Service.

7. Record transformer temperature rise during the rated current load tests.
   a. Take loss measurements at specified loads.
   b. Implant six thermocouples into secondary windings of transformer at locations approved by Resident Engineer and mount two thermocouples on transformer frame.
   c. Transformer temperature rise determined by any of the thermocouples shall not exceed value specified in Section 34 21 16.26, Transformer-Rectifier Unit.

8. Perform audible sound level tests in accordance with IEEE C57.12.91 except apply 3-foot distance and maximum sound level in accordance with Section 34 21 16.26, Transformer-Rectifier Unit.

F. DC Switchgear:
   1. Perform on the DC switchgear assembly.
   2. Perform the "design tests" specified in IEEE C37.20.1.
   3. Insert and remove one (1) circuit breaker element into connected position 200 times from disconnect position.
   4. Drawout mechanism shall function properly showing no signs of wear.
   5. Inspect main and auxiliary contacts for damage and weakness.
   6. Contacts shall sustain no physical damage or wear. No wear is permissible.
   7. Contacts shall make full contact with mating member as determined by Resident Engineer.

G. DC Circuit Breaker:
   1. Perform in accordance with design tests in IEEE C37.14.
   2. Follow schedule of design tests defined in IEEE C37.14.

H. DC Protection Relays and Control Devices:
   1. Perform in accordance with design tests in IEEE C37.90.
   2. Frame Fault Relay (Device 64 G and H): Following design tests are required:
      a. Continuous and Maximum Short Circuit Ratings: Demonstrate by test.
      b. Response Time and Maximum Trip Time: Demonstrate by test.
c. Maximum trip time for this device shall not exceed 50 ms.

I. DC Disconnect Switches:
1. Conduct a complete set of design tests on one switch of each type in accordance with IEEE C37.30.1 and IEEE C37.41. Resident Engineer may waive design testing and accept instead a notarized certified test report of a complete set of tests on a switch of the same design and ratings.
2. Switches to be tested and certified suitable for use on dc circuits with prospective fault current capabilities of 201 kA, or more.
3. Tests to be performed with switch(es) in enclosure assembled in closed, final operational configuration.
4. Mechanical Test: Subject a sample switch to a maximum number of openings and closings to establish a life cycle capability.
5. Continuous and overload current-temperature tests before and after.
6. Test mounting and operating hardware of switches and hardware to twice maximum operating load.
8. All tests shall be successfully completed to show that switches meet Specification requirements before final acceptance by Resident Engineer.

J. Substation Local Centralized Monitoring System (LCMS):
1. Perform with all accessories attached in accordance with design tests in IEEE C37.90.
2. Wiring Tests:
   a. Continuity of all wiring.
   b. Megohmmeter test at 2500 Vdc from all wiring to equipment case for 1 minute.
3. Demonstrate electrical operation and accuracy of all components.
4. Perform a dielectric test on field contacts for 1 minute to confirm the level of voltage isolation of 2000 Vdc. TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices.
5. Test from LCMS to initiating devices for proper operation.
6. De-bug and test IC/HMI application software to the satisfaction of Sound Transit before installing the IC/HMI in switchgear and beginning factory testing of the dc switchgear.

K. Battery: Design test for the battery shall comply with IEEE 1106.

L. Battery Charger: Tests for the battery charger shall comply with design tests described in NEMA PE5.

M. Traction Power Substation Factory Acceptance Tests
1. General Requirements:
   a. Perform test for each completely assembled substation at substation manufacturer's facility before shipping substation to site.
   b. Perform at ambient conditions unless a specific environmental or operating limit is necessary to demonstrate acceptable operation.
   c. Tests shall demonstrate that each substation is complete and ready for shipping to the site, both functionally and cosmetically.

2. Pretest:
   a. Perform for each substation using an approved test procedure and submit a pretest report.
   b. For offsite tests, travel arrangements for the Engineer's witness will not be made until a pretest report is submitted.

3. Wire and Cable Testing:
   a. Perform tests after factory wiring and terminations have been installed.
   b. Inspect wire and cable for physical damage and proper connections.
   c. Protect semiconductor devices against the test voltage by means of shorting jumpers or other methods accepted by Engineer, if they are not inherently protected by the circuit in which they are used.
   d. Continuity Tests: Check continuity from point to point and check for shorts to ground with an ohmmeter.
   e. Insulation Resistance Tests:
      1) Measure insulation resistance with a 1000 Vdc megohmmeter.
      2) Measure insulation resistance between conductor and ground.
      3) Test cables after terminations are complete. Do not connect equipment to the cable system during tests.
      4) Acceptance Criteria for 600 V wire and cable: 10 Megohms for 1,000 feet when measured at 25 degrees C.
      5) Test Failure: If insulation resistance values are unacceptable, correct deficiency and retest. If the test fails again, replace the entire wire or cable segment.
      1) Passing Criteria: No insulation breakdown or excessive leakage current.
      2) Failures: Locate and determine the trouble, replace defective wires, cables or components, make necessary corrections to installation, and retest without additional cost to the Owner.
   g. Control circuit wiring: Test for continuity and insulation after termination.
h. Power and equipment branch circuits: Perform continuity test on conductors.

i. Three-phase loads: Verify circuit phasing.

N. Low-Voltage Panelboards and Enclosed Circuit Breakers:
1. Test circuits for connections in accordance with the wiring diagram.
2. Test that insulation resistance to ground of nongrounded conductors is a minimum of 10 megohms.
3. Test panelboard and load center enclosures for continuity to the grounding system.
4. Test operation of circuits and controls. When testing, operate each control a minimum of 10 times and each circuit continuously for a minimum of 1/2 hour.
5. Test that each panel has a balanced load.

O. Ancillary Systems:
1. Perform operational and functional tests on each auxiliary and ancillary system provided in this Contract, including but not limited to the following:
   a. Auxiliary panelboards.
   b. Auxiliary contacts.
   c. Door interlocks.
   d. Receptacles.
   e. Interior, exterior, emergency, and cubicle lighting. Measure lighting levels and confirm that minimum lighting levels are met as required by Section 34 xx xx, Substation Lighting;
   f. HVAC units and controls.

P. General Substation Operation:
1. Perform a functional test of substation operation.
2. Check the interlocks for proper functioning of alarms and operation of shutdown circuitry.
3. Use strip chart recorders or oscillographs as required to provide a permanent record of the protective functions.
4. Perform other tests as required by substation equipment manufacturer and Engineer to determine the acceptability of the installation and equipment.

2.02 FACTORY PRODUCTION TESTS

A. Traction Power Transformer:
1. Factory Dielectric tests in accordance with IEEE C57.12.91.
2. Applied-voltage and induced-voltage tests in accordance with IEEE C57.12.91.

3. Resistance measurements of all windings on all taps.

4. Ratio tests on the rated voltage connections and on all taps in accordance with IEEE C57.12.91.

5. Polarity and phase relation in accordance with IEEE C57.12.91.

6. No-load losses and excitation current in accordance with IEEE C57.12.91.

7. Partial Discharge Test:
   a. Perform after completion of all design tests.
   b. Subject transformer to an induced voltage of 1.5 times the rated voltage at a frequency between 100 and 400 Hz.
   c. Partial discharge extinction level shall be reached at an induced voltage of not less than 1.2 times the rated line-to-line voltage.
   d. Partial discharge extinction level will be defined as the point when the reading at 1.9 MHz is less than ten microvolts or 100 picocoulombs.

B. Rectifier:
   1. Dielectric tests in accordance with IEEE 1653.2.
   2. Continuity tests of all cables and buses.
   3. Rated voltage test in accordance with IEEE 1653.2.

C. DC Switchgear:
   1. Perform in accordance with IEEE C37.20.1:
      a. Dielectric tests.
      b. Mechanical operation tests.
      c. Electrical operation and control wiring continuity, except that control wiring continuity shall be verified by actual electrical operation of control devices.

D. DC Circuit Breaker:
   1. Perform on each dc circuit breaker in accordance with IEEE C37.14 prior to mounting inside dc switchgear:
      a. Calibration test.
      b. Control, secondary wiring and device check test.
      c. Dielectric withstand voltage test.
      d. No-load operation test.
   2. Perform on each DC circuit breaker after mounting in switchgear:
a. Operation test.
b. Position test: Disconnected, test, and connected positions.
c. Alignment test of primary and secondary contacts.
d. Interlocking test for all positions.

E. DC Disconnect Switch:
   1. Perform for each dc disconnect switch in accordance with production tests in IEEE C37.41.
   2. Conduct standard production tests on all switches to check the quality and uniformity of workmanship and materials used, including the following:
      a. Check for gaps, using a feeler gauge (or other approved method) at each contact and assembly point. Gaps are grounds for rejection.
      b. Test operation of all components.
      c. Perform power frequency dielectric withstand test.
      d. Test electric resistance of current path.

F. DC Protection Relays and Control Devices: In accordance with production tests in IEEE C37.90.


H. Substation Local Centralized Monitoring System (LCMS) and Rail Voltage Monitoring and Grounding System.
   1. Prior to Assembly: Test all components, including the LCD, panel meters and control devices for proper operation and function.
   2. After Assembly:
      a. Verify electrical operation in accordance with IEEE C37.20.1.
      b. Verify device accuracy in accordance with IEEE C37.20.1.
      c. Test control wiring continuity by actual electrical operation of control devices.
      d. Test inputs and outputs for proper operation and short circuits.

I. Burn-In Test of Each IED or IC:
   1. Place equipment in an environmental chamber and cycle continuously between zero degree C and 60 degrees C for 20 cycles.
   2. Each cycle shall be 8 hours in duration. Maximum and minimum temperature shall be continuously sustained for 3.5 hours in each cycle.
   3. Confirm each IED and IC performs as specified at completion of test.
PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL – FIELD INSTALLATION TESTS

A. General Requirements:
   1. Perform after complete installation of each traction power substation, including connecting wiring, before energization.
   2. Verify that all equipment is properly installed in accordance with approved drawings, in operable condition and all open inspection items and NCRs have been corrected.
   3. No equipment shall be energized or placed in operating mode until completion of Field Installation Testing and permission of Resident Engineer.

B. General Substation Operation:
   1. Perform a functional test of substation operation prior to energizing the substation. Energize only circuits of 600 V or less for this test.
   2. Check interlocks on enclosure and panels for proper function of alarm and shutdown circuitry.
   3. Use strip chart recorders or oscillographs as required to provide a permanent record of the protective functions.

C. Electrically Insulated Floor and Wall Tests:
   1. Perform hi-potential dielectric tests on the epoxy floor and wall insulation installed in each traction power substation prior to the installation of substation equipment.
   2. Provide a hi-potential tester with a voltage range of 0-15,000 Vdc and a current range of 0-2000 microamperes dc to perform the tests.
   3. Floor: Perform a wet mop test as follows:
      a. Provide a sponge mop with a non-metallic handle. Provide a copper plate behind the sponge with a wire terminal to attach the test lead.
      b. Connect one lead from the tester to the copper plate and the other lead to the station ac ground bus.
      c. Apply 4500 Vdc from the hi-potential tester, using precautions such as insulated boots and hot gloves to protect the test technician.
      d. Saturate the mop with saline solution and mop the entire insulated floor with the room darkened. Re-saturate the mop as necessary.
      e. Leakage current greater than 50 microamperes or visible arcing indicates inadequate dielectric strength of the epoxy coatings; apply additional layers of epoxy until the leakage current is lower than 50 microamperes and there are no visible arcs.
   4. Walls: Perform a Copper Disk Test as follows:
a. Provide a copper disc 4 inches in diameter and 1/4-inch thick. The disk shall have a non-conductive handle and wire terminal to attach the test lead.

b. Connect one lead from the tester to the copper disk and the other lead to the station ground bus.

c. Place the copper disc on the wall insulation at a minimum of ten locations selected by Resident Engineer where the laminate is fastened to the wall with mechanical fasteners.

d. Apply 4500 Vdc for 120 seconds and record the leakage current.

e. If leakage current is greater than 50 microamperes, epoxy insulation shall be applied to the fastener to increase the insulation and the wall retested.

D. Wire and Cable Testing:

1. Perform tests after factory or field wiring has been installed in place and terminations installed.

2. Continuity Tests: Check continuity from point to point and check for shorts to ground with an ohmmeter.

3. High Potential Tests: In accordance with Section 34 21 28, Low-Voltage Conductors and Cables.

4. Test 600 V control circuit wiring for continuity and insulation after termination.

5. Protect semiconductor devices against the test voltage by means of shorting jumpers or other methods accepted by Resident Engineer, if they are not inherently protected by the circuit in which they are used.

6. DC Feeder Cables and other 2.4 kV conductors:
   a. Conduct test prior to cables being connected to rails or OCS.
   b. Perform test in accordance with Section 34 21 28, Medium Voltage Conductors and Cables.

7. Medium Voltage Cables: Test in accordance with Section 34 21 28.

E. Grounding in TPSS: Verify correct grounding of all equipment requiring grounding.

F. Test of the Substation Ground:

1. Test the ground at each substation in accordance with IEEE Standard 81.

2. An established metallic ground may be utilized as the test reference.

3. Perform other tests as required by substation equipment manufacturer and Sound Transit to determine the acceptability of the installation and equipment.

G. DC Switchgear:

1. High-potential Tests:
a. Disconnect high-resistance ground relay, Device 64, for this test.

b. Perform test between the AC and DC switchgear, including fasteners and the isolation laminate, at 2500 Vdc. Leakage current shall be less than 50 microamperes.

c. Perform test from dc switchgear enclosure to ground at 2500 Vdc, Leakage current shall be less than 50 microamperes.

d. Perform continuity tests on all interconnecting cables and buses.

e. Perform insulation test on all interconnecting feeder cables using a 2500 Vdc megohmmeter for 1 minute.

f. Test positive and negative feeder buses to ground using a 2500 Vdc megohmmeter for 1 minute.

g. Verify load measuring and reclosing functions.

2. Verify proper operation of all interlocks and Kirk key schemes.

H. DC Disconnecting Switches:

1. Perform continuity and insulation tests on all interconnecting cables and buses.

2. Test positive or negative feeder buses to ground using a 2500 Vdc megohmmeter for 1 minute.

3. Verify proper operation of all interlocks and Kirk key schemes.

I. DC Relays:

1. Verify proper operation and setting of all relays.

2. Where applicable, settings to be in accordance with approved relay coordination curves.

J. Traction Power Transformers:

1. Perform insulation tests between windings, between windings and ground, and between the core and ground using a 2500 Vdc megohmmeter for 1 minute.


K. Rectifiers:

1. Perform insulation tests between the diode strings and rectifier enclosure using a 2500 Vdc megohmmeter for 1 minute.

2. Perform insulation tests between the enclosure and ground using a 2500 Vdc ohmmeter for 1 minute.

3. Perform a functional test of all temperature, protective, monitoring and alarm devices.

L. Substation Local Centralized Monitoring System (LCMS):
1. Perform control circuit functional test by actuating control switches and observing the operation of circuit breakers.

2. Simulate alarm functions at each device at the switchgear, transformer and rectifier and verify correct indication at substation LCMS.

3. Verify correct operation of each function and display.

M. Frame Fault (Device 64G & H) Tests:
   1. Connection: As shown in the one-line diagram.
   2. Test: Simulate a 1500 Vdc to frame fault by passing low dc current levels through the relays.
   3. Approval: Provide graphical outputs, including time-current characteristics, onsite at the time of testing for review and approval.
   4. Criteria: Maximum total clearing time including operation of the 64G & H relay, the substation lock-out relay, and the tripping of the main AC and DC feeder breakers shall not exceed 300 ms.
   5. Field Adjustments: In the event that certain test conditions do not conform to the test procedure, make necessary field adjustments, perform necessary calculations to demonstrate successful test completion, present the calculation method to Resident Engineer for review, and include with the test report.

N. Rail Voltage Monitoring and Grounding Devices Tests:
   1. Test: Demonstrate proper function of the rail-to-earth relay and rail-to-earth clamping device.
   2. Simulate rail-to-earth voltages and currents to show that the substation will alarm, trip, and short circuit rail to earth when the voltage and currents exceed the alarm, trip, and short circuit points specified in Section 34 21 16.27, Rail Voltage Monitoring and Grounding Devices.

O. Battery:
   1. Perform after substation equipment has been installed on site.
   2. Perform acceptance tests in accordance with IEEE 1106.

P. Battery Charger:
   1. Perform after substation equipment has been installed on site.
   2. Perform in accordance with NEMA PE5.

Q. Ancillary Systems: Perform operational and functional tests on auxiliary and ancillary systems including HVAC units, auxiliary panelboards, auxiliary contacts, door interlocks, receptacles, emergency lights, fans, and all systems provided in this Contract that are not specifically called out in this Section.

3.02 FIELD SYSTEM TESTING

A. Perform tests in this section after energization; obtain permission from Resident Engineer prior to energizing substation.
B. Adjust Traction Power Transformer taps for optimum dc output voltage based on ac service voltage at each location.

C. Transformer Rectifier Unit: Perform audible sound test inside substation in accordance with IEEE C57.12.91, except for the following:

1. Apply 3-foot distance, energized condition, and maximum sound level in accordance with requirements of Section 34 21 16.26, Transformer-Rectifier Unit.

2. Perform with HVAC system turned off.

D. Transfer Trip, ETS, including all FCC ETS, and SSS Test: Perform complete functional and integrated tests to verify operation in accordance with the requirements in Section 34 21 16.25, Traction Power Substation Installation and Section 34 21 19.16, Dc Switchgear.

E. Dc Short Circuit Tests:

1. Close in Fault Test:
   a. Purpose: This test is performed to determine system Imax and adjust protection relay settings.
   b. Preparation:
      1) Disable the automatic tripping elements of the dc breakers during this test in order to obtain data of actual fault current levels.
      2) Place a jumper across line and load terminals of the feeder breaker and move to the connected position.
      3) Energize only one TPSS. The adjacent substations are de-energized.
   c. Test: Using a short circuit switch (SCS), apply a bolted fault from line side of the dc feeder breaker to the negative bus.
   d. After Test: Verify that the dc breaker trips according to protection coordination study.

2. Mid Fault Test:
   a. Purpose: This test is performed to determine the system resistance and inductance profile and adjust protection relay settings.
   b. Preparation:
      1) Disable the automatic tripping elements of the dc feeder breakers.
      2) Energize only one TPSS. The adjacent substations are de-energized.
   c. Test: Using a short circuit switch (SCS), apply a bolted fault from messenger wire to rail 2,500 feet from TPSS.
   d. After Test: Verify and apply new protective settings if necessary.
e. Re-test by repeating Mid Fault Test with new settings to verify that the breaker trips according to new protection setting.

3. Distant Fault Test:
   a. Purpose: This test shall verify that the dc protection relay will detect a fault at the furthest point from the substation under test and adjust protection relay settings.
   b. Preparation: Energize only one TPSS. The adjacent substations are de-energized.
   c. Test: Using a short circuit switch (SCS), apply a bolted fault from OCS to rail at the location furthest from the feed point of the substation under test.
   d. After Test: Verify that the dc breaker trips according to protection coordination study.

3.03 SYSTEM INTEGRATED TESTING

A. Procedures refer to Section 01 95 00, System Testing and Integration.

B. After completion and acceptance by Sound Transit of the field tests, perform integrated testing, as described below.

C. SCADA Tests:
   1. Test all SCADA points from initiating device to IC for proper operation.
   2. Coordinate and test from each initiating device to Central Control.

D. Rail Voltage Monitoring and Grounding Devices Tests:
   1. For each substation, provide a 48-hour chart recording of the rail-to-earth voltages and currents measured at the terminals of the Negative Cubicle during simulated revenue service.
      a. Set horizontal and vertical scale such that both time duration and magnitude of rail-to-earth voltages/currents are clearly readable.
      b. Resolution shall be no less than 100 ms for time and 2 V for voltage
   2. Iteratively adjust the annunciation and trip setpoints until optimum settings have been determined to the satisfaction of Sound Transit. This process may require several weeks or more of monitoring and adjusting settings.
   3. Submit settings to Sound Transit after all of the following conditions are met:
      a. The substation remains on line for 14 Days without a nuisance trip (tripping under normal operation without apparent reason) including times when adjacent substations are removed from service for at least 1 hour.
      b. The recommended settings conform to IEEE 80 for safe touch and step potential.
   4. Chart Recording after acceptance of settings:
a. For each substation, after the Rail Voltage Monitoring and Grounding Devices have been set and the settings accepted by Sound Transit, submit a 48-hour chart recording of the rail-to-earth voltages and currents measured at the terminals of the dc switchgear for record and for final approval.

1) Set horizontal scale so that both time duration and magnitude of rail-to-earth voltages/currents are clearly readable.

2) The recording shall be taken on a weekday, during actual or simulated revenue service and shall become a part of the as-built record documentation.

E. Train Start Tests:

1. Contractor shall furnish the test procedure for these tests, but Sound Transit will direct the tests. Sound Transit will furnish four-car trains AW2 loaded.

2. Purpose:

a. Demonstrate the traction electrification system will allow multiple trains to start under full load with one TPSS out of service.

b. Adjust protection relay settings as part of testing. Include final settings in train start test report.

END OF SECTION
SECTION 34 21 16.15
DC DISCONNECT SWITCHES

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes: Motorized and manual operated no load break DC disconnect switches.

1.02 REFERENCES
A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:
   1. ASTM International (ASTM):
   2. Institute of Electrical and Electronics Engineers (IEEE):
   3. National Electrical Manufacturers Association (NEMA):
      a. NEMA 250 - Enclosures for Electrical Equipment (1,000 Volts Maximum).
      b. NEMA ICS 1 - Industrial Control and Systems: General Requirements.
      c. NEMA ICS 2 - Industrial Control and Systems Controllers, Contactors and Overload Relays Rated 600 Volts.

1.03 SUBMITTALS
A. Product Data: Complete manufacturer's descriptions, catalog data, and information including materials and model numbers.
   1. Where there is a Kirk key scheme, provide descriptions, catalog data, materials and information including detailed arrangement drawings.
B. Shop Drawings: Manufacturer's general and detail arrangement drawings for switches, operating linkage and enclosures.
   1. Provide all dimensions including enclosure.
   2. Provide installation instructions.
C. Switch Mounting: Provide mounting details for all types of switch arrangements.
   1. Submit seismic calculations for each type of switch mounting arrangement sealed by a registered professional engineer in the State of Washington.
D. Testing: Submit test procedures and test reports in accordance with Section 34 21 16.11, Traction Power Substation Testing.
E. Operation and Maintenance Data:
1. Description of the switch and its components.
2. Manufacturers’ operating and maintenance instructions, parts list, illustrations and diagram for components.
3. Recommended list of spare parts.

PART 2 - PRODUCTS

2.01 DC DISCONNECTING SWITCHES

A. Description: Enclosed, single-pole single-throw, or single-pole double-throw air break switch type with manual or motorized operator.

1. Design shall comply with IEEE C37.34, ASTM B187/B187M, NEMA ICS 1, and NEMA ICS 2.
2. Ratings:
   a. Voltage: 1500 Vdc.
   b. Insulation Level: Dry 1 minute power frequency 5.7 kV rms (energized parts to ground and gap between positive and negative parts).
   c. Continuous Current Ratings: As indicated in Contract Drawings, without the switch contact temperature rise exceeding 50 degrees C above a maximum ambient temperature of 40 degrees C.
   d. Momentary Peak Current Withstand: Minimum 90 kA.
   e. Short-Time Current Rating: Minimum 70 kA, average, for 0.25 second.

B. Switch Contacts:

1. Moving and stationary contact surfaces: Silver-plated copper.
2. Other current-carrying parts: High-conductivity copper or copper alloy.
3. Contacts shall be self-aligning, wear compensating, and with initial wiping action.
4. Hinge and jaw contacts shall be bolted-pressure type with non-ferrous or stainless steel self-clamping mechanism, or other approved high-pressure type contact arrangement.

C. Switch Insulation Structure:

1. Materials used for the switch assembly insulation structure shall be noncombustible, non-hygroscopic, and tracking resistant.
2. The mechanical strength of the insulation structure shall match the stresses imposed by the rated momentary current, opening and closing operations.

2.02 SWITCH ENCLOSURES

A. Switch enclosures shall be suitable for applications indicated in Contract Drawings, and designed for outdoor use to NEMA 250, Type 3R.

B. Provide a separate enclosure for each switch, except as indicated.
C. Enclosure Material: Molded, fire-retardant fiberglass-reinforced polyester:
   1. Glass to resin ratio: 30 to 70.
   2. Thickness: Minimum 1/4-inch.
   3. Tensile strength: Minimum 1,500 psi.
   4. Water absorption: Maximum 0.05 percent in 24 hours.
   5. Add inhibitors to protect enclosure from possible deterioration due to ultraviolet rays.
   7. Provide a protective coat of clear polyester gel on exterior surfaces.

D. Exterior hardware: Stainless steel or non-ferrous metal.

E. Doors:
   1. Hinges: Continuous stainless steel, providing 120 degrees minimum swing opening.
   2. Provide doorstop.
   3. Provide door gasket.
   4. Latch: Three-point, stainless steel.
   5. Operating handle: Non-metallic.
   6. Locking provisions: Heavy duty lugs to accept one heavy-duty padlock provided by Contractor. Keying requirements to be determined by Sound Transit.

F. Viewing windows: Provide one or more, as required, shatterproof, to permit observation of switch position status from outside enclosure with door closed.

G. Cable entrance: Provide conduit hubs, as required or as indicated.

H. Exterior mounting tabs: Suitable to hold switch and box with two tabs removed.

I. Signage: Provide each disconnecting switch enclosure with a warning sign and nameplate by contractor as follows:
   1. Material: Corrosion resistant and ultraviolet protected.
   2. Location: Mount on enclosure door.
   4. Nameplate designations: Will be provided by Resident Engineer.

J. Mimic bus: Provide on front of all outdoor pad mounted and indoor type disconnect switch enclosures.
   1. Mimic bus shall be factory applied, red color, 3/8-inch wide and minimum 1/32-inch thick.
2. Outdoor pad mounted enclosure mimic bus material and installation shall be weather proof.

K. Non-current Carrying Metallic Parts:
   1. Interior of boxes: Shall be insulated.
   2. Exterior: Insulate mounting hardware protruding through enclosure wall.
   3. No grounds shall be present in switch boxes.

2.03 PAD-MOUNTED OR WALL-MOUNTED MANUAL-OPERATED DISCONNECTING SWITCH ASSEMBLY

A. Provide each switch with an insulated manual-operating handle, externally mounted on the outside.

B. Provide corrosion resistant nameplates permanently secured to enclosure to show OPEN and CLOSED positions of switch contacts.

C. Provide operating handle with heavy-duty lugs to accept one padlock, provided by Contractor, in the fully open or closed switch positions. Sound Transit to provide padlock keying requirements.

D. Provide each switch with two Form C position limit switches, one to operate at the fully open position and the other to operate at the fully closed position.
   1. Both limit switches shall be open for all intermediate disconnecting switch positions.
   2. The status of each limit switch shall be displayed on LCMS HMI and SCADA screen where indicated on the Contract Drawings.
   3. Wire to a terminal block with 2000 V insulated #12 AWG stranded cables.

E. Provide locks on switch handles to allow switches to be locked in closed or open position.

F. Interlocking system, where indicated, shall be self-supervising and be of fail-safe design; it shall not permit switch operation in the event of a component failure. System design shall comply with NEMA ICS 1 and ICS 2.

G. Provide mechanical interlock as indicated.

2.04 CABLE TERMINATION

A. Provide line and load side disconnecting switch terminals with silver-plated copper bus complying with ASTM B187/B187M to accommodate the number and size of DC power copper cables, entering from below or from above, as indicated.

B. Provide switch terminals with the proper size and quantity of NEMA terminal lugs.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install disconnect switches at locations shown on Contract Drawings.

B. Install switches in accordance with approved manufacturer’s instructions. Provide anchor bolts and anchorage items as required.
C. Coordinate installation with design of disconnect switch supporting hardware, feeder cable installation, support and routing, and ensure designs are fully integrated with the installed attachments.

D. Attach operating mechanisms such that handles do not intrude into the track clearance envelope.
   1. In general, operating handle shall move away from or parallel to track.
   2. Install switch such that a person operating the switch will not be in danger from passing vehicles.
   3. If doubt exists about which way to face a disconnect switch, obtain clarification from Sound Transit.

E. Install operating handle at a height that allows switch to be operated easily by a person standing on the ground.

F. Adjust switches after installation to provide proper mating of the blades and easy alignment and operation.

G. Provide cable clamps on line and load side of switches to prevent stress on connectors and switch jaws.

END OF SECTION
SECTION 34 21 16.17
PREFABRICATED TRACTION POWER SUBSTATION BUILDING

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes: Pre-fabricated Traction Power Substation (TPSS) buildings, including the following:

1. Building structure.
2. Insulated walls, ceiling and floor.
3. Heating, Ventilating and Air Conditioning (HVAC) system in buildings.
4. See Section 34 21 16.25, Traction Power Substation Installation, for building appurtenances such as dielectric walls and floor, and required components not included in other sections.
5. Substation Lighting, for interior and exterior lights

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. American Institute of Steel Construction (AISC):

2. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE):

3. ASTM International (ASTM):
   a. ASTM A384/A384M - Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
   b. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   c. ASTM E136 - Standard Test Method for Behavior of Materials in a Vertical Tube Furnace at 750° C.

4. National Electrical Manufacturers Association (NEMA):
a. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum).
b. NEMA ICS 6 - Industrial Control and Systems: Enclosures.

5. Illuminating Engineering Society (IES)
a. IES LM-79 Approved Method: Electrical and Photometric Measurements of Solid-State Lighting Products
b. IES LM-80 Approved Method: Measuring Luminous Flux and Color Maintenance of LED Packages, Arrays and Modules

6. National Fire Protection Association (NFPA)
a. NFPA 70 National Electrical Code

7. Underwriters Laboratories Inc. (UL)
a. UL 924 Standard for Emergency Lighting and Power Equipment
b. UL 8750 Standard for Light Emitting Diode (LED) Equipment for Use in Lighting Products

8. State of Washington:
c. International Mechanical Code (with amendments by Authority Having Jurisdiction)
d. Washington State Energy Code

1.03 SUBMITTALS

A. Product Data:

1. HVAC unit, including HVAC controller and a description of how units will meet specified requirement to alternate operation every two weeks.

2. Paint. Refer to Section 34 21 27, Metal Fabrication and Finishes.

3. Substation Lighting:

a. Document that proposed luminaires fully comply with Contract Documents.
b. Indicate luminaire construction, photometric performance, installation, and maintenance requirements.
c. Include clear and legible product specifications, drawings and illustrations of sufficient detail to describe the following:
   1) Luminaire housing, hardware, and finishes.
   2) Light controlling elements.
3) Electrical components and provision for conduit entry.

4) Support details: Indicate weight of luminaire.

B. Shop Drawings and Engineering Calculations:

1. Building Structural: Structural engineering calculations and drawings, sealed by a professional engineer registered in the State of Washington, and design data:
   a. Structural engineering design parameters and criteria, including equipment weight and seismic criteria, deflection criteria suitable for the insulated floor, including snow, wind and ice loading.
   b. Structural engineering calculations for sizing structural members, calculating maximum allowable bending, torsion, and flexure during installation and transportation, sizing and design of lifting eyes under worst case conditions, including snow, wind and ice loading.
   c. Sealed structural shop drawings for fabrication including a scaled floor plan, and wall and roof plans, showing equipment design, outlines, interlocking panels and weights, penetrations for conduits, ventilation ducts, door frames and openings.
   d. Sealed structural shop drawings showing details of fabrication including door construction and frames, joints, welds, and bolted connections.

2. HVAC: Mechanical engineering calculations and drawings, sealed by a professional engineer registered in the State of Washington, and design data:
   a. Sealed mechanical engineering calculations for sizing air conditioning, ventilation and heating per the specified criteria.
   b. Sealed mechanical engineering shop drawings suitable for installation and fabrication of the mechanical equipment including air conditioning, ventilation and heating. Drawings shall include a scaled floor plan showing equipment outlines and weights, penetrations for conduits and ducts.

3. Railings, stairways, and ladders: Drawings showing details of fabrication, including welding.

4. Substation lighting: Lighting layout with proposed luminaires indicated by manufacturer and model number. Show the calculations that specified lighting levels are achieved with proposed luminaires.

C. Qualifications Statements: For manufacturer, erectors and welders.

1.04 QUALITY ASSURANCE

A. Manufacturer Qualifications: Manufacturer of the pre-fabricated metal buildings shall be performed by a company regularly engaged in the production of metal buildings for pre-fabricated traction power substations or similar applications, and as approved by Resident Engineer.

1. Manufacturer shall have constructed at least 50 similar buildings in the last 10 years.
PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. The Traction Power Substation building shall be a weatherproof, insulated, walk-in unit suitable for the installation and housing of all specified Substation equipment.

B. Access to the Substation equipment will be from the sides and the rear. The construction of the building will allow the removal of all major equipment from outside or inside of the Substation building without disassembly of the equipment.

C. Contractor shall inspect foundation for proper fit prior to manufacture. Contractor is solely responsible for proper fit of substation on foundation.

D. Size: Traction power building size shall be identical to the existing typical Link mainline traction power building and constructed from approved shop drawings, unless otherwise shown on Contract Drawings.

2.02 BUILDING DESIGN

A. Design substation building to withstand live roof loading, wind loading, and seismic loading and the stresses caused during loading, transportation, unloading, and installation.

B. Comply with the following codes and standards; if conflicts exist, the most restrictive requirements shall apply:

1. AISC 303 and AISC 360.

2. Traction power substation building shall meet standards of Washington Department of Labor and Industries Factory Assembled Structures (FAS) and bear the required FAS Insignia.


2.03 BASE

A. Fabricate from structural steel beams and steel cross members welded into a rigid unit of adequate strength to allow lifting of the complete assembly including all equipment.

1. Structural steel:
a. Hot-dip galvanize before welding in accordance with Section 34 21 27, Metal Fabrication and Finishes.

b. Avoid using structural steel members with nonsymmetrical sections to minimize warpage and distortion during hot-dip galvanizing, as recommended by ASTM A384/A384M.

2. Welds:
   a. Mask steel in weld areas before galvanizing in accordance with Section 34 21 27, Metal Fabrication and Finishes.
   b. Coat welds as required in Section 34 21 27, Metal Fabrication and Finishes.

B. Design the base to permit natural ventilation between Substation enclosure and concrete foundation to prevent condensation and buildup of water.

C. Grounding Pads
   1. Provide a copper grounding pad at each corner of the building, bonded to the interior of the steel base, for connection of a 2-hole cable lug.
   2. Provide openings in floor for access, with removable cover plates as described below in Article titled “Floor.”
      a. Size: Minimum 10 inches x 12 inches.
      b. Location: Coordinate access openings with equipment layout such that no part of the minimum size opening will be obstructed by the equipment. Openings in equipment provided for cable entrance may also be used for access to grounding pads.
   3. Connect each grounding pad to a substation ground bus, as specified in Section 34 21 16.25, Traction Power Substation Installation.

D. Lifting Lugs:
   1. Provide removable lifting lugs securely bolted to the base, suitable for safely lifting and placing the building, complete with equipment, on its foundation without structural, mechanical or electrical damage.
   2. Lifting lugs shall be designed to prevent damage to exterior paint surfaces.
   3. The lugs shall be constructed such that they will fit on any housing furnished under this Contract. Provide one complete set of lifting lugs to Sound Transit.

2.04 FLOOR

A. Material: Steel plate, minimum 1/4-inch thick.

B. Fabrication: Stitch-welded to the base.

C. Strength: The floor shall withstand the weight of the heaviest circuit breaker, transformer or other equipment item which may have to be moved along the floor, without significant deflection.

D. Cutouts:
1. Provide as required for conduit entry, cable entry, substation grounding and hatch for access basement

2. Cover openings not covered by equipment with removable cover plates:
   a. Insulated floor: 1/4-inch glastic or epoxy with non-metallic hardware to latch it in place
   b. Non-insulated floor: 11 gage steel with stainless steel hardware to latch it in place.

### 2.05 WALLS

**A. Exterior walls:**

1. **Material:** Sheet steel panels, of a grade to be determined by Contractors structural design engineer.
2. **Thickness:** Minimum 11 gage (base metal only).
3. **Coating:**
   a. Galvanneal meeting the requirements of ASTM A653/A653M with minimum coating weight A25.
   b. Galvanneal shall not be quenched by the steel manufacturer or galvanizer or chemically treated in a way that inhibits powder coating.
4. **Interlock adjoining panels with J-type interlocking, as indicated in Figure 1, below.**
5. **Seal seams with manufacturer recommended caulk.**

**Figure 1: Cross Section Wall Panels J-Type Interlocking**

**B. Interior walls:**

1. **Material:** Same as exterior walls, above.
2. **Coating:** Same as exterior walls, above.
3. **Thickness:** 14-gage (base metal only).

### 2.07 ROOF

**A. Shed type, with a pitch as shown on the Contract Drawings, fabricated from interlocking sheet steel panels:**

1. **Material:** Same as exterior walls, above.
2. Coating: Same as exterior walls, above.
3. Thickness: Same as exterior walls, above.
4. Interlocking: J-type, with standing seams and rain caps over seams, as indicated in Figure 2, below.
5. Seal seams with manufacturer recommended calking.

2.08

1. Figure 2: Cross Section Roof Panels Standing Seams With Rain Cap

B. Roof penetrations:
1. Shall be used only with approval of the Engineer.
2. If used, shall be minimal with each flashed and waterproofed.

2.09 BUILDING COMPONENTS AND MATERIALS

A. Gutters and Downspouts:
1. Provide one gutter on each long side of the enclosure; provide one downspout at each end of each gutter, a pair for each gutter.
2. Material: Same as exterior walls, above.
3. Coating: Same as exterior walls, above.
4. Thickness: Same as exterior walls, above.
5. Design:
   a. Size with sufficient capacity to handle the historical maximum volume of rain for the City.
   b. Angle downspouts at the bottom and extend far enough from building to divert water minimum 12 inches beyond outside of foundation wall.

B. Entry Doors:
1. Provide a minimum of two entry doors, located as indicated on the Contract Drawings.
3. Insulation: R value in accordance with applicable energy code.
4. Size: Not smaller than those shown on the Contract Drawings.
5. Hinges: Stainless steel with stainless steel hinge pins.

6. Panic hardware: One or three point crash-bar safety latches to permit opening doors from within under all conditions.

7. Locks: Self locking, tamper proof locks integrated with entry door handles.
   a. All locks shall be keyed alike.
   b. Sound Transit to provide keying requirements.
   c. Provide two keys for the building.

8. Door Closer:
   a. Heavy duty, highly corrosion resistant; all external body components of aluminum, zinc alloy or stainless steel material with stainless-steel fasteners.
   b. Shall close door firmly and have hold-open position.

9. Sealing:
   a. Doors shall be tightly sealed with neoprene gaskets.
   b. Secure seals to the doors so as to allow easy replacement.
   c. Design of doors shall prevent intrusion of water around the seams.

10. Warning signs: Provide a sign on each entry door stating “DANGER: HIGH VOLTAGE” and “KEEP OUT”.

C. Exterior Equipment Access Doors:

1. Provide hinged doors where shown on Contract Drawings.
   a. Equipment doors shall allow access to the rear of the ac switchgear, transformer, rectifier, and dc switchgear from the outside of the substation for regular maintenance.
   b. Opening the transformer rear doors shall allow removal of the transformer as a unit from the outside of the substation.

2. Material: 11 gage sheet steel, galvannealed in accordance with ASTM A653/A653M.

3. Provide door stiffeners as required to improve rigidity of door panels.

4. The exterior equipment access doors shall meet or exceed the requirements of NEMA ICS 6 for weatherproof NEMA 250 Type 4 enclosures.

5. Latches: 3-point, padlockable, heavy duty stainless steel switchgear type.

6. Hinges:
   a. Stainless steel, with stainless steel hinge pins and hardware.
   b. Provide a minimum of three concealed hinges.
7. Door gaskets: Neoprene. Secure seals to the doors so as to allow easy replacement.

8. Door stop: Provide on the bottom of each door to hold it in the open position
   a. Provide ANSI Device No.33 microswitch on doors. Upon opening of a door, provide the followings:
      1) Alarm to LCMS and SCADA
      2) Trip the ac lockout relay, ANSI Device 86.

9. Padlock:
   a. Provide one heavy-duty master-keyed padlock for each external door.
   b. Sound Transit to provide keying requirements.
   c. Padlock shall be located at working height referenced to actual final grade elevation at site.

D. Removable Exterior Panels:
   1. Weight: Less than 75 lb.
   2. Joints: Sealed and gasketed similarly to doors.

E. Steps and Railings: Provide galvanized steps, ladders, and railings.

F. Thermal and Acoustical Insulation:
   1. General Requirements:
      a. Insulating materials shall have a certified classification of "non combustible" as defined by ASTM E136.
      b. Flame proofing of insulating materials will not be acceptable. Proof of certification shall be by one of the following:
         1) UL label or listing.
         2) National Bureau of Standards test results.
         3) Certified test report from a nationally recognized testing laboratory.
   2. Floor Insulation: Solid insulating panels.

2.10 HEATING, VENTILATING AND AIR CONDITIONING (HVAC)
   A. Provide a thermostatically controlled HVAC system with HVAC controller for two air conditioners.
   B. General Requirements:
      1. Provide two wall-mount HVAC units.
2. The HVAC units shall be suitable for installation against a solid barrier not more than 6 feet away. Condenser air shall be exhausted in a way that the exhausted air will not be recirculated back to the intake/economizer of the unit.

3. HVAC units shall be capable of maintaining the interior temperatures specified above at ambient temperatures specified in Section 34 21 10, Traction Electrification System General Requirements.

4. Units shall be identical to each other.

5. Maintain positive pressure within the space in all operating modes.

6. HVAC units are powered by the TPSS auxiliary power transformer.

C. Design Criteria:

1. Heat gain: Design for the following simultaneous conditions:
   a. 100 percent loading of the traction power transformer-rectifier unit.
   b. Exterior design conditions per International Energy Conservation Code with City amendments.
   c. Maximum solar heat gain.

2. Temperature: Maintain the interior temperature between 55 degrees F and 76 degrees F under all operating conditions.

D. HVAC Units:

1. UL listed, AHRI performance certified, meeting minimum efficiency requirements of the Washington Energy Code.

2. Enclosures: Stainless steel.

3. TPSS auxiliary Provide coated condenser coils.

4. Finish color: Match finish color of substation enclosure.

E. Size auxiliary power transformer to power all HVAC units simultaneously and continuously at their 100 percent rating.

F. Ventilation system: Provide sufficient air changes to prevent battery-evolved hydrogen gases from exceeding a 1 percent concentration level.

G. Heating: Design based on conduction and infiltration heat loss with exterior design conditions per International Energy Conservation Code with City amendments and substation de-energized (no heat gain from interior equipment).

H. Air Intakes:

1. Provide outside air sensors in the fresh air intake duct.

2. Provide ducts either on air intake or condenser exhaust to prevent air recirculation from unit exhaust.

4. **Filters:**
   a. Provide MERV 11 filtration per ASHRAE 52.2.
   b. Exterior: Provide tamper-proof hardware for filters located on exterior of enclosure.
   c. Provide filter clogged alarm device wired to LCMS.

I. **Alarms:**
   1. If substation interior temperature reaches 85 degrees F send alarm to LCMS and SCADA. Temperature alarm set point shall be field adjustable.
   2. If any HVAC filter clogs send alarm to LCMS and SCADA.
   3. If any HVAC unit fails send alarm to LCMS and SCADA.

J. **Economizer Cycle Cooling:**
   1. Provide HVAC units in conjunction with an economizer to allow TPSS interior cooling using only exterior air when that air is less than 70 degrees F.
   2. Provide gasketed, motorized dampers to seal the enclosure when economizer cooling is not possible.

K. **HVAC Controller:**
   1. Provide an HVAC controller that complies with the requirements in this Section, and has the following features:
      a. Field controllable.
      b. Includes an HMI displaying current temp, programmable schedule, 12/24 hour clock, and on screen programming.
      c. Programmable.
      d. Produced by a manufacturer whose main line of products is HVAC.
      e. Compatible with heating and cooling and multi-stage fan systems.
   2. Maintain the interior temperature between 55 degrees F and 76 degrees F under all operating conditions.
   3. Provide internal ambient temperature sensor at the control power battery bank location.
   4. Provide controls to manually and automatically alternate the HVAC units every 2 weeks to minimize wear and tear on any unit.

L. **Installation:** Provide condensate drain pipe per International Mechanical Code with City amendments.

2.11 **SUBSTATION LIGHTING**

A. Performance criteria
1. Each substation shall have interior and exterior lighting to provide the specified minimum light levels.

2. Minimum Lighting Levels
   a. Interior: 70 footcandles at 30 inches above the aisle floor.
   b. Exterior: 2 footcandles, measured at ground level.
   c. Emergency Lighting: Minimum 1 footcandle at 30 inches above the aisle floor.
   d. Minimum lighting levels shall be maintained throughout the TPSS. Average lighting level shall not be used to meet this requirement.

B. Luminaires

1. Interior of Substation Building:
   a. Type: Ceiling mounted, linear LED luminaire.
   b. Lens: Wraparound style, polycarbonate or high-impact acrylic diffuser, UV resistant, with even light distribution, secured to the housing with fasteners.
   c. Standards: Complying with UL 8750.
   d. Correlated Color Temperature (CCT): 5000-6000 K.
   e. LED Driver: Field replaceable.
   f. MTBF: Minimum 50,000 Hours.
   g. Acceptable Manufacturer/ Product: Kenall N1048 Series, Lithonia FEM LED or approved equal.

2. Exterior of Substation Enclosure:
   a. General:
      1) Wall-mounted, vandal-resistant, LED luminaire, full cut-off type.
      2) UL listed for 40 degrees C maximum ambient and wet locations with IP66 ingress rating. Luminaire shall comply with IES LM-79 and LM-80 and be DLC (Design Lights Consortium) qualified.
   b. Housing:
      1) Die-cast aluminum, with a hinged door secured by captive stainless steel, tamper-resistant screw.
      2) Housing shall incorporate cooling fins specifically design for cooling LED light source and driver.
      3) Approximate dimensions of complete luminaire: 6 inches wide x 7 inches high x 4 inches deep, including back-box. Provide with wire guard.
c. Finish: Epoxy or polyester powder-coat paint, white, or as directed by Resident Engineer.

d. Optical:
1) Sealed LED compartment with anodized, mirror-finish, forward-throw reflector, high-output bright-white (5000K CCT) LED, impact resistant tempered glass lens and silicone sealing gaskets.
2) Luminaire shall deliver at least 1400 lumens, be rated full-cutoff with BUG rating B1-U0-G0 or better, and be suitable for wall-mounting 8 feet or greater above surrounding surface.

e. Electrical:
1) Integrated electronic LED driver with integral surge protection shall be mounted to housing for effective cooling.
2) Provide luminaires with integral photocontrol or a single NEMA-style, aimable photocontrol wired in luminaire circuit.

f. Acceptable Manufacturer/Product: Lumark XTOR2A-WT-WG or approved equal.

3. Lighting Within Substation Vault/Basement:

a. General: Ceiling mounted outdoor general purpose gasketed, vapor-tight LED luminaire with corrosion-resistant aluminum body, frosted glass diffuser, and metal guard.

b. Acceptable Manufacturer/Product: Lithonia OLVTCM or approved equal.

4. Emergency Lighting:

a. General:
1) Self-contained units containing lamps, battery, battery charger, controls, test switch, and status indicator.
2) UL 924 listed.

b. Housing: UV-stabilized, high impact, clear 0.120-inch polycarbonate or 18-gage steel, with a baked enamel finish.

c. Lighting Heads: High-output 6.5 W LED lighting heads; minimum two lamps per unit.

d. Battery:
1) Nickel-cadmium, 12 V, rechargeable, sealed, maintenance-free.
2) Capacity: Shall supply rated lamp load for 1-1/2 hours, minimum.
3) Life expectancy: 10 years.

e. Battery charger:
1) Solid-state, current-limited, temperature-compensated, short-circuit proof, and reverse-polarity protected with plus-or-minus 1 percent regulation.

2) Charger shall automatically maintain battery in fully-charged float condition and be capable of providing full recharge in 12 hours.

f. Unit controls: Shall energize lamps automatically upon failure of ac power supply and disconnect load before battery low-voltage limit is reached.

g. Acceptable Manufacturer/Product: Kenall METEL-series LED, or approved equal.

5. Lighting Inside Equipment Enclosures:
   a. General: Ceiling and side mounted, LED strip luminaire with clear, prismatic diffuser complying with UL 8750.
   b. Minimum illuminance: 30 footcandles at 1.5 feet.
   c. Correlated Color Temperature: 5000-6000 K
   d. Size: 30 centimeters or 12 inches long with 12 LEDs.
   e. MTBF: 50,000 Hours
   f. Acceptable Manufacturer/Product: LBFA Lux Bar LED light bar, or approved equal.

PART 3 - EXECUTION

3.01 BUILDING INSTALLATION

A. Install the Substation building on the existing building foundation as specified in Section 34 21 16.25, Traction Power Substation Installation.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:
   1. DC control power for Traction Power Facilities.
   2. Isolation transformer for AC loads in DC equipment.
   3. Low voltage AC generator connections for prefabricated TPSS’s control power system.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:
   1. Institute of Electrical and Electronics Engineers (IEEE):
   2. National Electrical Manufacturers Association (NEMA):
      a. NEMA 250 - Enclosures for Electrical Equipment (1000 Volts Maximum).
      b. NEMA PB 1 – Panelboards.
      c. NEMA PE 5 - Utility Type Battery Chargers.
   3. Underwriters Laboratory (UL):
      a. UL 67 – Panelboards.
      b. UL 489 - Molded-Case Circuit Breakers, Molded Case Switches, and Circuit-Breaker Enclosures.
      c. UL 1008 - Transfer Switch Equipment.

1.03 SUBMITTALS

A. Product Data: Submit for the following items unless otherwise specified:
   1. Batteries.
   2. Battery charger/eliminator.
   3. Disconnect switches in accordance with Section 26 28 15, Enclosed Switches and Fuses.
5. Isolation transformers.

B. Shop Drawings: Submit shop drawings and electrical diagrams in accordance with Section 26 24 12, Panelboards and Circuit Breakers, as follows:
   1. Panelboards.
   2. Circuit breakers.

C. Engineering Calculations: Submit engineering calculations for sizing battery, battery charger/eliminator, isolation transformers, and dc power supplies for each location.

D. Test and Evaluation Reports: Submit test procedures and test reports in accordance with Section 34 21 16.11, Traction Power Substation Testing.

E. Signage: Signage with procedure for disconnecting battery from control power system. Signage with procedure for transferring control power AC source between generator connection and regular AC panel.

F. Operation and Maintenance Data:
   1. Description of the DC control power system components.
   2. Manufacturer's operating and maintenance instructions, parts lists, illustrations and diagrams for components.
   3. Recommended list of spare parts.
   4. Wiring diagram for overall system, battery charger/eliminator and generator connection system including manual transfer switch.

G. Warranty Documentation.

1.04 TOOLS

A. Furnish one set of tools for battery maintenance for each TPSS.

B. Tools shall be for normal operation and maintenance of the batteries and shall include the following:
   1. One cell lifting sling complete with strap and spreader bar.
   2. One battery log book.
   3. One quart of terminal grease.
   4. One set of tools for maintenance.

1.05 QUALITY ASSURANCE

A. Control power equipment, including battery, battery charger/eliminator, disconnects, panelboards, fuses, and miscellaneous equipment shall be UL labeled or certified as conforming with the requirements of UL and IEEE or ANSI or by an Independent Testing Laboratory recognized by the State of Washington.
1.06 DELIVERY, STORAGE AND HANDLING
   A. Delivery: Ship batteries separate from the TPSS building.

1.07 WARRANTY
   A. Manufacturer’s Warranty - Batteries: Warrant batteries to be free from defects in materials and workmanship for 5 years and to have at least 80 percent of rated capacity for 10 years from the date of acceptance of the equipment.

PART 2 - PRODUCTS

2.01 DC CONTROL POWER
   A. DC control power voltage shall be 125 Vdc for all TPSSs.
   B. DC system shall consist of batteries, battery charger/eliminator, battery racks, DC distribution panelboard and accessories or DC power supply units and accessories to provide control power for the Traction Power Facilities.
   C. DC portion of the system shall be electrically isolated from ground.
   D. Battery and its associated charger/eliminator shall be connected in parallel.
   E. Battery may be used to supply heavy short-time current demands.
   F. When the AC supply power to the charger is interrupted, the battery shall supply all the required power for the specified load duty cycle.
   G. Provide DC monitoring relay and connect across the main DC bus.
      1. When main DC bus voltage drops to 90 percent of its nominal voltage, an alarm shall annunciate low auxiliary voltage and send to Link Control Center (LCC) via LCMS & SCADA.
      2. Set relay to drop out at 80 percent of the nominal DC control voltage. When the relay drops, trip and lock out the AC main breaker, trip the DC feeder breakers (do not lock out), trip the main DC circuit breaker, annunciate a loss of DC control power, and send to LCC via LCMS & SCADA.
   H. Provide a timer such that after a continuous 10 hours of battery charger outage, a timer shall trip and lockout the Medium Voltage (MV) AC circuit breaker and main DC circuit breaker via the 86 relay, and trip and lockout the DC circuit breakers via the 186X relays.

2.02 BATTERIES
   A. Manufacturers:
      1. Storage Battery Systems: Valve Regulated Pocket Plate type, or approved equal.
      2. ALCAD: Pocket Plate Range, or approved equal.
   B. Batteries shall be designed to provide float service under normal usage for the intended duty cycle.
   C. Battery shall be valve-regulated pocket plate, Ni-Cad, heavy-duty design, sealed cell type, consisting of individual cells in molded cases for durability, high impact resistant.
D. Batteries and chargers/eliminators provided in this contract shall be both physically and electrically interchangeable with Sound Transit existing Traction Power Facilities. Spares are to be shared between this contract and existing Link systems.

E. Size battery capacity in accordance with IEEE 1115.

F. Provide rated ampere-hours for a 10-hour discharge rate.

G. Base battery capacity on the following load duty cycle over a period of 10 hours at

H. 40 degrees C ambient from a fully charged state with the battery charger out of service.
   1. Normal continuous demand of substation auxiliary loads including protective devices, motor operated spring circuit breaker charger, tripping coil, indicating lights, lights inside switchgear, communication devices, Local Centralized Monitoring System (LCMS) and other substation auxiliary loads.
   2. A trip and reclose cycle of one DC feeder breaker every hour.
   3. A trip and reclose of the two AC breakers after 2 hours and again after 4 and 8 hours.
   4. A trip and reclose of the main DC breaker every 2 hours.

I. Battery Cell Containers.
   1. Containers shall be plastic, sealed, heat-resistant, and flame retardant.
   2. Containers shall not deteriorate or become cloudy upon exposure to the electrolyte.
   3. Cell covers shall be cemented in place to provide a permanent leak-proof seal.

J. Battery Terminal Posts.
   1. Sealed with compression rubber bushing and epoxy.
   2. Identify clearly and permanently.

K. Configuration: Batteries may be either stacked vertically or mounted horizontally in a cabinet or battery rack.

L. Connections:
   1. Connect batteries together into a battery bank using tin- or silver-plated solid copper bus bar and silicon bronze bolts, nuts and fasteners.
   2. Cable jumpers are not permitted for battery connection.
   3. Batteries shall be replaceable individually or in pairs without disassembling the entire battery bank or stack.

M. Provide battery bank with a stainless steel nameplate. Provide the following information:
   1. Manufacturer's name.
   2. Battery and cell type.
   3. Month and year of manufacture.
4. 1 minute, 1 hour and 8 hour ampere rating.
5. Ampere-hour capacity of C/8 (8 hours) and C/10 (10 hours).

2.03 BATTERY DISCONNECT SWITCH
A. Provide a two-pole fused knife switch in a dedicated NEMA 250 Type 12 enclosure accordance with Section 26 28 15, Enclosed Switches and Fuses to permit isolation of the battery from the loads and battery charger.
B. Circuit breaker in DC distribution panelboard for battery isolation purpose is prohibited.
C. Signage: Provide signage above dedicated enclosure to clearly describe the procedure for disconnecting battery from control power system.
D. Coordinate fuse rating and switch size with dc circuit breaker in battery charger.

2.04 BATTERY CHARGER/ELIMINATOR
A. Provide battery charger/eliminator with the following characteristics:
1. Completely automatic, fully regulated, two-stage, silicon-controlled-rectifier type complying with NEMA PE 5, except as modified herein.
2. Sufficient capacity to support all normal loads and simultaneously recharge the batteries from 1.75 V per cell to 85 percent of battery capacity within 8 hours.
3. Provide temperature compensation function.
4. Provide electrical isolation between the input and output.
5. Provide an output circuit breaker.
6. The battery charger shall be cooled by natural air convection.
7. Audible Noise Level: Less than 55 dbA measured in accordance with NEMA PE 5.
8. Both physically and electrically interchangeable with one of Sound Transit existing types in Traction Power Facilities, except Central Link. Spares are to be shared between this contract and existing systems.
B. Output voltage shall provide a float charge voltage in accordance with the battery manufacturer's recommendation.
C. Current Limiting:
1. For load or fault conditions of very low load resistance (such as a dead short), the battery charger shall "fold back" (limit both the output current and voltage).
2. Current limit shall be factory preset to provide the capacity described above and be field adjustable from 90 percent to 110 percent of the factory preset value.
3. Normal operation shall automatically resume when the overload or short circuit is removed.
D. Enclosure: NEMA 250, Type 12. Provide with a hinged front panel and a minimum of two latches.
E. Battery charger/eliminator shall be powered from the local AC panelboard via a lockable circuit breaker with lock.

F. Furnish battery charger with an output voltmeter and an output ammeter.
   1. Type: 3.5 digit LED or LCD type.
   2. Accurate to 1 percent of the full-scale reading.
   3. Mount to the charger enclosure front panel.

G. Provide ground fault protection on the battery charger output by verifying the positive and return currents sum to zero.
   1. The sensitivity of the ground fault protection shall be field adjustable to eliminate nuisance failures.
   2. Protection shall shunt trip the charger output circuit breaker.

H. At a minimum, the following statuses shall be detected and annunciated on both LCMS and SCADA as a battery charger failure:
   1. Loss of DC output.
   2. Loss of AC input supply.
   3. Ground fault.
   4. 1500 Vdc shorted to 125 Vdc.
   5. Low DC output voltage.
   6. Main DC circuit breaker position.

2.05 ISOLATION TRANSFORMER
A. Size according to load plus 20 percent.
B. Single phase 120/240V primary - 120/240V secondary.
C. UL listed, NEMA Type 3R encapsulated enclosure.
D. Electrically shielded.
E. UL Class 200 degrees C insulation system, 115 degrees C temperature rise under full load.

2.06 DC DISTRIBUTION PANELBOARD
A. NEMA PB 1, UL 67.
B. Designed for two-wire, 125 Vdc ungrounded power distribution service.
C. Enclosure: NEMA 250 Type 12, fabricated from galvanized steel, surface-mounted.
D. Finish: In accordance with Section 26 24 12, Panelboards and Circuit Breakers.
E. Cover and Trim.
1. Designed for surface mounting.
2. Hinged front cover with a minimum of two latches.
3. Dead front.

F. Bus Bars: Copper with the current density limited to 1000 A per square inches.
1. Provide a separate ground bus with full rating.

G. Main incoming terminals shall be for connection of batteries and battery charger.

H. Provide surge protection device rated for required application with minimum 25 kA peak surge current capacity. Provide status LED.

I. Circuit Breakers: UL 489.
1. Two-pole.
2. Bolt-on type.
3. Trip mechanism shall be thermal-magnetic and trip-free.
4. Breaker “on”, “off,” and “tripped” positions shall be clearly indicated by the handle position.
5. Provide main circuit breaker with auxiliary contacts for annunciation.
   a. Contacts shall be factory wired to a terminal strip for connection to the LCMS and SCADA.
   b. Annunciate tripped or open main circuit breaker.
6. Branch Circuit Breakers: Minimum of 100 A frame size, minimum 10,000 A interrupting rating at 250 Vdc.

J. Spares: Provide each panelboard with 10 percent spare branch circuit breakers and space for the addition of a minimum of four future two-pole branch circuit breakers.

2.07 LOW VOLTAGE GENERATOR CONNECTIONS

A. Transfer Switch:
1. Basis of Design: ASCO Power Technologies, or approved equal.
2. Rating: 240 Vac 150 A.
3. Listings: UL 1008 switch and NEMA 1 enclosure.
4. Voltage sensing for both normal and emergency, pilot lights to indicate transfer switch position, output contacts to indicate transfer switch position, and solid neutral with full rated terminal lugs.

B. Generator Plug.
1. Basis of Design: Cooper Crouse-Hinds Arktite brand part AREA10426, or approved equal.
2. Plug: 100 Amp, 2-inch hub, three-wire, four-pole, 600 Vac/250 Vdc.
3. Housing: Weatherproof, metallic with extra grounding contact.

C. Fused Disconnect: Comply with Section 26 28 15, Enclosed Switches and Fuses.

PART 3 - EXECUTION

3.01 ISOLATION TRANSFORMER APPLICATION

A. Provide an isolation transformer in each location where an AC circuit is used to power equipment within DC equipment, such as DC switchgear heaters and rectifier fans.

B. Supply power as indicated.

3.02 INSTALLATION

A. Control power components shall be installed in accordance with Section 34 21 16.25, Traction Power Substation Installation.

B. Generator connection to be mounted integral to exterior of wall of substation as shown on Contract Drawings.

C. Connect battery charger ground terminal to substation main ground.

END OF SECTION
STANDARD SPECIFICATIONS

SECTION 34 21 16.22
TES – DC SURGE ARRESTERS

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
1. DC Surge Arrester requirements for traction electrification system.

1.02 REFERENCES
A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:
1. ASTM International (ASTM):
   a. ASTM B3 - Standard Specification for Soft or Annealed Copper Wire.
   b. ASTM B172 - Standard Specification for Rope-Lay-Stranded Copper Conductors Having Bunch-Stranded Members, for Electrical Conductors.
2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE C62.11 - Standard for Metal-Oxide Surge Arresters for AC Power Circuits (>1 kV).

1.03 SUBMITTALS
A. Product Data:
1. Surge arresters.
2. Extra-flexible cable.
3. Insulated cable.
B. Shop Drawings: Shop drawings to scale showing:
1. Surge arrester installation.
2. Barriers if surge arresters are installed in vault undersubstation.
C. Design Testing:
1. Submit a test procedure and test report.
2. Test to Failure:
   a. Perform test on one surge arrester.
b. Mount surge arrester as it will be mounted on the substation, or in approved alternate mounting arrangement, complete with cables connected.

c. Test to failure at two times energy rating and verify that arc clears and that enclosure does not fail catastrophically.

D. Production Testing:
1. Submit a test procedure and test report.
2. Energy Test:
   a. Test each surge arrester and provide test report.
   b. Test at 80 percent of rated energy.
3. Voltage Test (minimum requirement; additional tests may be performed):
   a. Test each surge arrester after completion of the energy test and provide test report.
   b. Test using a calibrated AC dielectric test set capable of reading leakage values.
   c. Apply 1940 Vac for 30 seconds. Maximum allowable leakage current 1.5 mA.
   d. Increase voltage to 2154 Vac for 5 seconds. Maximum allowable leakage current 3.0 mA.

PART 2 - PRODUCTS

2.01 DC SURGE ARRESTERS

  A. DC surge arresters shall be the same as and interchangeable with existing DC surge arresters for ST East/Northgate Light Rail Link.

  B. Basis of Design: Reuel, IMP-1 Metal Oxide DC Surge Arrester, as distributed by Balfour Beatty Rail, Inc.

  C. DC surge arresters shall be outdoor style, intermediate class and shall be designed, constructed and tested in accordance with the general requirements of IEEE C62.11.

  D. Surge arresters shall be epoxy encapsulated and be of the metal oxide varistor type.

  E. The arresters shall be rated to withstand normal operating line transients of up to 5000 Vdc of either polarity to ground without damage.

  F. The MCOV shall be at least 1940 V.

  G. The arresters shall limit the reverse voltage across the rectifier silicon diodes to a value less than 75 percent of the peak-reverse-voltage rating of the diode by limiting the rise of the transient on the positive to negative bus.
2.02 GROUNDING CONDUCTOR

A. Extra-flexible cable: Copper, 4/0 AWG, Class I stranding, minimum length 3 feet, bare or insulated, ASTM B3, ASTM B172.

B. Conductor connection:
   1. Manufacturer: Burndy Hyground, Thomas & Betts, or approved equal.
   2. Splice: C-type compression connector.

PART 3 - EXECUTION

3.01 TPSS INSTALLATION

A. Substation arresters shall be connected between the negative bus and the ground mat and between each DC feeder termination in each circuit breaker cubicle and the ground mat as shown in the substation single line diagrams.

B. Arresters in substation shall not be mounted inside rectifiers or switchgear.

C. Surge arresters shall be installed as shown on Contract Documents in accordance with manufacturer’s instructions:
   1. DC surge arresters shall be located in the vault below the DC switchgear, or in an area as directed, and shall be separated from the DC switchgear enclosure such that the arresters will fail in a safe manner. Protection shall be placed around the arresters so that in the event of a failed arrester, damage to any surrounding equipment will be minimized.
   2. If located in vault below substation, surround surge arresters with clear polycarbonate barrier and suitable warning signs to prevent accidental contact by maintenance personnel.
   3. Connect surge arrester to ground-mat pigtail using extra-flexible copper ground.
   4. If ground-mat pigtail is too short, provide cable and splices to connect ground-mat pigtail to substation surge arrester extra-flexible copper ground.

3.02 OCS INSTALLATION

A. Surge arresters shall be located on top of overhead contact system (OCS) poles at the end of each feeder cable from TPSS. Additional surge arresters shall be located and connected to OCS in each direction on each section 1,000 feet from TPSS and mid-section between TPSSs.

B. Mount in a position such that catastrophic failure shall not permit a positive cable to contact a pole.

C. Install in accordance with surge arrester manufacturer’s instructions.

D. Energized side of surge arrester: Provide 2.4 kV rated insulated cable from surge arrester to contact wire or switch.

E. Ground side of surge arrester: Provide extra-flexible cable, minimum three feet long, and connect to surge arrester.
F. Provide insulated or bare cable from extra flexible cable to ground. Provide splice between extra-flexible cable and cable to ground for a continuous path to ground.

G. Install conductors with a minimum number of bends. Bends shall be no less than 8-inch radius.

H. Connect insulated ground cable to dedicated surge arresters ground system.

I. On elevated structure, run insulated ground cable to nearest support column and connect to dedicated surge arresters ground system.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Requirements for providing the Substation Local Centralized Monitoring System (LCMS) and the Intelligent Electronic Devices (IED) in each Traction Power Facility for overall substation control, protection, and monitoring.

2. LCMS includes the following:
   a. Station Industrial Computer or equivalent PLC.
   b. Human Machine Interface.
   c. Local/remote control switch.
   d. Terminal blocks for connection and interface with the SCADA system and other communications systems.

3. Integration of transfer trip with existing substations.

1.02 REFERENCES

A. Abbreviations and Acronyms:

1. HMI: Human Machine Interface.
2. IC: Industrial Computer.
3. IED: Intelligent Electronic Devices.
4. LCMS: Local Centralized Monitoring System.
5. SCADA: Supervisory Control and Data Acquisition.

B. Definitions:

1. Intelligent Electronic Device: Refers to any digital or numerical based protection, metering, control, or monitoring device that has processing, recording and reporting capabilities used in traction power substations or DC section tie breakers.

C. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. Institute of Electrical and Electronics Engineers (IEEE):


2. International Electrotechnical Commission (IEC):
   a. IEC 60255-21 Electrical Relays - Part 21: Vibration, Shock, Bump and Seismic Tests on Measuring Relays and Protection Equipment:
      1) IEC 60255-21-1 Section One: Vibration tests (sinusoidal).
      2) IEC 60255-21-2 Section Two: Shock and bump tests.
      3) IEC 60255-21-3 Section Three: Seismic tests.
   b. IEC 60529 - Degrees of Protection Provided by Enclosures (IP Code).
   c. IEC 61000-4-3 Electromagnetic Compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test.

1.03 SUBMITTALS

A. Product Data:
   1. Industrial Computer.
   2. Each IED.
   3. Terminal blocks.
   4. HMI and components.
   5. System block diagram for each LCMS, additions and modifications to existing substations.

B. Shop Drawings:
   1. Shop Drawings of LCMS.
   2. Switchgear Internal devices/components layout plans.
   3. Ladder logic diagrams, flowcharts and schematics with contacts and devices properly labeled for all ICs and HMI application software.
   4. Wiring and interconnection diagrams.
   5. Schematic diagram of software interlocking between traction power equipment.

C. Bills of Material of LCMS.

D. Samples: Submit samples of the terminal blocks and control components, along with a description of the intended use of each component.

E. Test Procedures and Reports: Submit in accordance with Section 34 21 16.11, Traction Power Substation Testing.

F. Submit a detailed design of the HMI User Management System.
G. Submit a detailed I/O list for SCADA, for each TPSS, cross passage and wayside equipment.

H. Submit a detailed description of software interlocking between traction power equipment.

I. Submit full-scale color views of each display.

J. Provide complete, Windows-based application software including source code and documentation for user’s future maintenance, development, and restoration.
   1. Provide final version of firmware and documentation of firmware used on the Project.
   2. Provide all applicable parameterization files for media converters and gateways.

K. Qualifications Statements:
   1. Service Proven Design: Submit documentation to establish service proven history for both hardware and software. Include details of the application history, including number of units in operation, length of time, location and type of application.

L. Operation and Maintenance Data:
   1. Submittal information identified above.
   2. Manufacturer’s operating and maintenance instructions, parts list, illustrations and diagram for components.
   3. Recommended list of spare parts.

1.04 SOFTWARE INTELLECTUAL PROPERTY RIGHTS

A. All software developed under this Contract, including source code, shall become the property of Sound Transit.

B. Relay settings and downloading interface software shall be the property of Sound Transit.

C. IC/HMI application software development environment for all phases of the application including program development, documentation and machine startup shall be the property of Sound Transit.

1.05 QUALITY ASSURANCE

A. Certification and Labeling:
   1. IEDs and ICs shall be UL labeled.
   2. The enclosure shall be UL labeled or certified as conforming to the requirements of UL and ANSI for an Industrial Control Panel.
   3. If equipment is not available with a UL label, it may be furnished with a Field Evaluation label provided by a Testing Laboratory approved by the Washington State Department of Labor and Industries (L&I) in accordance with Section 34 21 10, Traction Electrification System General Requirements.

B. Software Quality Assurance: In order to ensure the quality of the LCMS software, utilize a software quality assurance plan in accordance with IEEE 730. The plan shall describe a mechanism for orderly software development.
1.06 SERVICE PROVEN DESIGN

A. IEDs and ICs shall be of a proven design in accordance with the following criteria:

1. Have at least 15 identical units in operation in a similar application in railroad or rail transit service for a minimum of 3 years.

2. Software shall either be of a proven design in accordance with the criteria specified above or shall meet the requirements of this Specification for development of new software.

PART 2 - PRODUCTS

2.01 GENERAL

A. Provide all necessary hardware, software and diagnostic equipment to ensure a fully operational and coordinated system.

B. A typical TPSS LCMS configuration diagram shall be shown on the Contract Drawings.

C. Alternate LCMS arrangements are permitted as described in this Section and as approved by the Resident Engineer.

D. If IC alternative with higher configuration is required, it shall be approved by Resident Engineer prior to commencing work.

E. IEDs, ICs, and HMIs shall meet requirements called out elsewhere in these Specifications for the ANSI device or devices they are replacing.

F. HMI inputs, outputs and displays shall be the same as those provided for existing Northgate and East Link substations.

G. For factory testing of IEDs or ICs used in place of ANSI devices, comply with requirements indicated in Source Quality Control article, below.

H. IC and HMI shall be used for overall substation control and monitoring.

I. The outage of LCMS shall not impact the substation local control and protection functions.

J. Logging and display of events by all LCMS and IED devices shall be time stamped to a resolution of 1 millisecond.

2.02 IED APPLICATION

A. Provide IEDs for the following functions associated with protection, measuring, and control in the TPSS:

1. Reclosing/Load measuring (ANSI Device 182/183).

2. Transfer trip and transfer trip lockout (ANSI Devices 85RX and 85NX).

3. Transfer trip of substations with DC tie switches closed to adjacent substation(s) in service.

4. Emergency Pushbutton (ANSI Device 5).

5. Transformer and Rectifier Fan Control (ANSI Device 23).
6. Phase Sequence (ANSI Device 47).
7. Associated transfer trip and reclosing logic.
9. Rail Voltage Monitoring and Grounding System (ANSI Device 64V).
10. Rate of rise (ANSI Device 150).
11. Rectifier overtemperature (ANSI Device 26R).
12. Undervoltage (ANSI Device 27).
14. Phase fault time overcurrent (ANSI Device 50/51).
15. Ground fault time overcurrent (ANSI Device 50N/51N).
17. Over-voltage (59).
18. 125 Vdc control voltage shorted with 1500 Vdc (ANSI Device 59A).
19. High resistance frame fault detection and monitoring (ANSI Device 64G/64H).
20. Position of DC breaker (ANSI Device 72F).
21. Rectifier diode failure alarm (ANSI Device 98).

B. In addition to those device and functions shown on the Contract Drawings the following functions shall be performed by individual devices which are wired to the IC to provide their output directly and shall not be IC controlled.

1. AC/DC lockout relay (ANSI Device 86/186).

2.03 GENERAL HARDWARE REQUIREMENTS

A. Voltage: Substation IEDs, ICs, and HMIs shall be powered by 125 Vdc plus or minus 15 percent.

B. Input and Output (I/O) Contact, Substation: 125 Vdc type and optically isolated. I/O contacts shall be dry type.

1. Electrical Rating: Make 30 A, carry for 3 seconds or longer, and carry 5 A or higher continuously.
2. Mechanical Durability: Greater than 100,000 operations.
3. Provide 25 percent spare I/O points for every individual unit.
4. I/O terminals shall be Interchangeable within the identical units in other Sound Transit TPSSs.

C. Storage Environment: Minus 25 degrees C to plus 70 degrees C and 25 degrees C to 55 degrees C at 95 percent humidity.

D. Ambient Operating Environment: 0 degrees C to 55 degrees C, 95 percent non-condensing humidity, and no corrosive gas.
E. Mechanical Shock and Bump Withstand Level: IEC 60255-21-2 Response and Withstand Section Class 1.

F. Vibration Withstand Level: IEC 60255-21-1, Response and Withstand Section Class 2.

G. Seismic Withstand Level: IEC 60255-21-3 Class 2.

H. Electromagnetic Field Impulse Withstand Level: IEC 61000-4-3, 10 V/m.

I. Electromagnetic Field Radio Frequency Withstand Level: IEEE C37.90.2, 35 V/m.

J. Enclosure Protection Level for IEDs: IEC 60529, IP52 or approved equal.

K. Main protection relays for medium voltage (MV) AC feeder and 1500 Vdc feeders shall be equipped with fault recording function to capture analog oscilloscope waveforms and digital pre-fault and post-fault data. The fault record shall be sent to substation IC after each capture.

L. Main protection relays for MVac feeder and 1500 Vdc feeders shall have an internal battery which can keep the setting, alarm/event lists and fault records from being lost in case the substation DC control power supply is out of service.

M. Provide test switch for every main IED and power meter.

N. Provide memory within IC to serve as the memory for storing latest events, alarms, and fault records during a disconnection between the IC and SCADA.
   1. After connection is restored, current device status and any active alarms shall be uploaded to SCADA.
   2. Memory shall be able to store 10,000 events, 10,000 alarms and 50 fault records which are oscilloscope waveforms.

2.04 LCMS ENCLOSURE REQUIREMENT

A. Install LCMS IC, HMI, and all accessories in a separate enclosure, located on wall as shown on Contract Drawings.

B. Construction: NEMA Type 12 dust-tight single hinged door enclosure, fabricated from 11-gage steel, with continuously welded or bolted seams.

C. Door:
   1. Gasket with neoprene.
   2. Provide with a pad-lockable handle with a three-point latch system.
   3. Prime and finish paint to match the switchgear. The exterior color shall be according to Section 34 21 27 Metal Fabrication and Finishes.

D. Hardware and Accessories: Stainless steel.

E. Internal Back-Panel: Removable, stud-mounted, and located as shown for the mounting of relays and terminal strips.

2.05 LCMS GENERAL REQUIREMENTS

A. Provide the following:
   1. Monitoring and control of the traction power system equipment.
2. Monitoring of all unsafe, erroneous, or unknown conditions or combinations of conditions.

3. An interactive interface between the LCMS and traction power system personnel (HMI).

4. A self-diagnostic routine to respond promptly, safely and predictably to detected faults within the LCMS.

B. Communication:
1. Provide communication between the LCMS and IEDs.
2. Provide communication between the LCMS and SCADA.
3. Collect the information from devices without a communication link through a dry-type input contact.
4. Send out commands to devices without a communication link through a dry-type output contact.

C. Sampling:
1. Sample input conditions at rates sufficient to detect and remedy unsafe or damaging conditions in the shortest possible time.
2. Sampling rates and program execution times shall be such that the control system is not the limiting factor in response to unsafe or damaging conditions.
3. Design software to ensure that the timing requirements for safety-related tasks are always met.

D. Application software shall correctly handle times and dates for the time span from calendar years 2010 through 2100. Clock format shall be 24-hour local time with adjustments as necessary for Daylight Saving Time.

E. Time Synchronization:
1. Provide time synchronization between IEDs, IC, and HMI to ensure that the clock in the IEDs is always synchronized with the IC, HMI, and the SCADA mother clock.
2. If protection/monitoring devices are not provided with a time synchronization function, the outputs of these devices shall be time stamped by either ICs or other IEDs that have a time synchronization function.

2.06 HUMAN MACHINE INTERFACE GENERAL REQUIREMENTS

A. HMI Unit: Provide clear display, easy operation and monitoring, with a realistic graphical representation of the traction power system being monitored as approved by the engineer.

1. Provide a Windows-based user interface on touch screen.
2. Provide connection options for external periphery units (keyboard, mouse, and laptop), e.g. via a USB interface.

B. HMI Processor:

1. Minimum 64 bit RISC CPU.

C. HMI Touch Screen:
   1. Touch Elements on the Screen: Contact-sensitive operating elements, such as circuit breakers, keyboard, buttons, input fields and message windows.
   2. Size: 15-inches diagonal.
   3. Resolution: Not less than 1024 x 768 pixels.
   4. Operation:
      a. Provide the status of the traction power system.
      b. Provide interface to perform open/close operations on traction power system equipment.
      c. Touching the relevant buttons and input fields displayed shall intervene directly in system operation.
      d. Touch elements are operated by touching them lightly with a finger.

D. HMI Control Level:
   1. Refer to Section 34 21 10, Traction Electrification System General Requirements, for information on the three control levels for TPSS switchgear.
   2. Provide Local/Remote options on HMI:
      a. Local option selected: The switchgear that has been set to Remote at equipment level is controllable from LCMS HMI only. LCC level is not able to send control command to the switchgear.
      b. Remote option selected: LCMS is not able to send operation command to any switchgear. All switchgear that has been set to Remote at equipment level is controlled remotely from LCC.
   3. Provide “Local” indication LED beside HMI touch screen. The LED shall be on when LCMS level “Local” is selected.

2.07 HMI USER MANAGEMENT SYSTEM

A. Provide a user management system to prevent the operable screen objects from being operated by unauthorized personnel.

B. Provide a user management tool for Sound Transit to define users, passwords and access rights with up to five authorization levels. A single master password shall be provided for all equipment under this section. This master password shall be delivered only to Resident Engineer. Passwords shall only be modifiable through the engineering software tool using the engineering laptop by authorized personnel.

C. Provide at least three pre-defined authorization levels initially:
   1. View = Not authorized to make operations.
   2. Control = Authorized to make operations.
   3. Engineering/System manager = All rights.
D. If an element is operated that is protected by the user management system, the login window shall automatically appear.

1. Provide a logoff mechanism to user when user finishes the operation.

2. Provide automatic logoff to reduce risk of operation by unauthorized personnel. The automatic logoff period shall be programmable and set initially for 5 minutes.

E. The password character string entered in user management system shall be represented by placeholders (*) in the password input field.

F. Acknowledgment of alarms shall be done through a manual push button above the HMI on the exterior of the LCMS cabinet and does not require a password.

G. Only a user with the appropriate authorization level can bypass the interlocking function to operate the interlocked equipment.

2.08 HMI FUNCTIONAL REQUIREMENTS

A. Open/close operations through HMI shall include at least two steps:

1. First:

   a. Selection of the object to be operated (for example, the selection of a circuit breaker).

   b. Object selection shall consist of at least two steps:

      1) Selection of the object.

      2) Confirmation of the object selection.

2. Second:

   a. Selection of the operation (for example, close or open operation on breaker).

   b. Operation selection shall consist of at least three steps:

      1) Selection of the operation.

      2) Confirmation of the operation.

      3) Execution of the operation.

3. A combined message window is not allowed; each step above shall have an individual window.

4. Selection, confirmation and execution information shall be displayed completely. No abbreviations are allowed.

5. Selection and confirmation of operation shall be automatically cancelled within 1 minute if the operation is not executed.

B. Inappropriate Operation: Display an interlocking alarm message window to the user when inappropriate operation is attempted.

C. Automatically display a numeric/alphanumerical screen keyboard directly after an input field is touched on the touch screen that requires a password or text entry.

D. After the user completes input, hide the screen keyboard automatically.
E. Provide a confirmation and cancel button.
   1. Provide a button with a toggle to bring up or hide the screen keyboard.

F. A view/window becomes active after being touched.

G. If the screen has not been touched for 2 minutes, the display shall restore to the substation single line diagram view, regardless of which windows have been activated.

H. A help button shall be automatically displayed when the user potentially needs help.
   1. Provide additional information and operating instructions in the Help texts.
   2. Help Text Examples:
      a. For an input field, provide information on permissible value ranges.
      b. For an alarm message, provide information related to the cause and its elimination.

2.09 HMI SCREENS

A. Color Code:
   1. Provide different colors to indicate the energization status of traction power system equipment on the touch screen.
      a. The color function shall indicate the energized, de-energized or uncertain state of every single component, including the busbar and feeder cables.
      b. There are no exceptions to the following color code for equipment symbols on the single line diagram and no other colors are permitted:
         1) Energized Equipment: Red.
         2) De-energized Equipment: Green.
         3) Uncertain Equipment State: Grey.
      c. Display flashing red color text “Energized” beside each piece of equipment when it is first energized and solid Red after 10 seconds.
   2. The status of the IEDs, ICs, and HMI s shall also be displayed on the touch screen. Equipment symbols of the IEDs, ICs, and HMI s shall use the following color code and no other colors are permitted:
      a. Good Condition: Green
      b. Bad Condition: Red
      c. Uncertain Condition: Grey

B. Application Views in HMI Touch Screen: Provide the following six views:
   1. Substation One-Line Diagram View:
      a. The typical display of this view shall represent the Contract Drawing. Changes from the Contract Drawings shall be approved by Resident Engineer.
b. The status (including the color) of the traction power equipment on the touch screen shall be displayed in real time and updated at least every 2 seconds.

c. This view shall provide open/close operation of the equipment in accordance with the HMI user management system.

d. If any protection function is triggered, the related equipment and alarm field shall flash until it is acknowledged.

2. Traction Power System Sectioning Diagram View:

a. The typical display of this view shall represent the Contract Drawing. Changes from the Contract Drawings shall be approved by Resident Engineer.

b. The status (including the color) of the traction power equipment on the touch screen shall be displayed in real time and updated at least every 2 seconds.

c. If any protection function is triggered within the viewed section, the related substation icon shall flash and Substation One-Line Diagram View shall pop-up automatically.

d. HMI view shall display TPSS where operations are and TPSS’s in both directions from the operation substation as indicated on the Contract Drawings. Display shall be in real time indicating circuit breakers and manual disconnect switches position(s).

3. Local Centralized Monitoring System Diagram View:

a. This view shall display the status of the HMI, IC, and IEDs. The 125 Vdc control power system status shall be displayed on this view.

b. If a device fault occurs, the related icon shall flash until it is acknowledged.

4. Event List View:

a. Event view shall display operating statuses and fault messages concerning the traction power system and IEDs, ICs, and HMI.

b. Display in this view record of logging in/out, and record of values measured and stored periodically, such as current, voltage, etc.

c. Event List shall be user definable to add additional event items. Any event item shall be able to convert to Alarm item. These modifications to events or alarms can only be implemented through the use of an engineering laptop by personnel with the appropriate authorization.

5. Alarm List View:

a. The typical display of this view shall represent the Contract Drawings. Changes from the Contract Drawings shall be approved by Resident Engineer.

b. Alarm list view shall display fault messages concerning the traction power system and the IEDs, ICs, and HMI.
1) Acknowledgment of alarms shall be done through a manual push button above the HMI on the exterior of the LCMS cabinet and does not require a password.

2) The alarm message shall continue to flash until it is acknowledged.

3) A blue LED shall be provided next to the alarm acknowledgment pushbutton to indicate the alarm status of the LCMS. Below are the three states of the blue LED relative to the alarm status of the LCMS.
   a) Blinking: Alarms present that have not been acknowledged.
   b) Solid on: Alarms present but have been acknowledged.
   c) Off: No alarms present.

c. Alarm list shall be user definable to add additional alarm items. Modifications to alarms can only be implemented through the use of an engineering laptop by personnel with the appropriate authorization.

6. Annunciation View: Annunciation view shall follow the same style as Northgate and East Link annunciation.

C. HMI Trouble: In addition to the touch screens, an extra LED shall be provided to indicate “HMI Trouble” in case the touch screen fails to display any information.

2.10 IC/HMI APPLICATION SOFTWARE DEVELOPMENT ENVIRONMENT REQUIREMENTS

A. Provide a user-friendly PC/Windows based development environment suitable for IC/HMI application software updating and modification.

B. The environment shall be dedicated solely to creating control/monitoring software. It shall use familiar, standardized editors bundled into a single application.

C. The environment shall include a graphics editor and online help that simplify development of IC/HMI application software.

D. The environment shall comply with Microsoft Windows Graphical User Interface (GUI) and IEC 61131-2 standards for programmable logic controllers.

E. Provide de-bug, documentation and machine startup facilities in the environment.

F. Provide complete user training for the application of development environment in accordance with Section 01 79 00, Training.

G. Provide complete user documentation for the environment in accordance with Section 01 78 23, Operation and Maintenance Data.

2.11 LAPTOP AND ASSOCIATED SOFTWARE FOR MAINTENANCE

A. Provide three laptops with associated cords, ports, comprehensive relay setting and downloading interface software and related operating system at the beginning of the project.

B. Provide a comprehensive IC/HMI application development environment with above laptops for all phases of the application including program development, documentation and machine startup.
C. Laptops shall comply with the following:
   2. CPU Speed: 2.6 GHz minimum, Dual-Core minimum.
   3. RAM: 8 GB minimum, DDR3, 1600 MHZ minimum.
   5. Audio: Stereo speakers & speaker port, microphone port.
   6. Display: Minimum 15” diagonal, HD Graphics Support, VGA, HDMI.
   7. Ports: Minimum 3 USB 3.0 ports, VGA, HDMI, speaker, microphone.

2.12 INTERFACE WITH SUPERVISORY CONTROL AND DATA ACQUISITION (SCADA)
   A. Provide TCP/IP RJ45 communication channel to interface with SCADA through an interface cabinet.
   B. The LCMS shall, at a minimum, provide the information to SCADA in accordance with approved Traction Electrification Systems SCADA Points I/O List.
   C. Control command to the substation equipment from the Link Control Center shall be implemented by LCMS.
   D. The request to close any DC feeder breaker shall be governed by the load-measure reclose system.
   E. The substation shall be provided with sufficient logic to ensure any response to a remote closure request will not result in an unsafe condition or cause damage to the Substation or any of its components.
   F. AC and DC feeder breakers shall be equipped with remote closing capability via SCADA. Once connected and tested remotely, the close function only shall be disabled in a manner approved by Resident Engineer.

2.13 TRANSFER TRIP
   A. General:
      1. Fiber optic monitoring and transfer trip shall be integral to protection relays.
      2. Integrate transfer trip with existing substations.
   B. Non-Adjacent TPSS:
      1. If an adjacent substation DC tie switches are closed, DC breakers not already open shall be tripped. The transfer trip signal continues to the next adjacent substation that is energized and shuts down that substation, as described below.
      2. This energized non-adjacent substation would be the substation supplying power to the same section of OCS as the originating substation.
   C. Transfer Trip Communication:
      1. Provide fiber optic cable as the communication medium between substations for transfer trip function.
2. Provide interface to and termination of the fibers for a complete operating transfer trip function.

3. Monitor the condition of the fiber optic cable continuously.

4. Generate an alarm and send to LCMS if a fault condition is detected.

D. Transfer Trip Function, Initiated by DC Breakers:

1. Initiate direct transfer tripping between feeder breakers supplying power to the same section of OCS. See Non-Adjacent TPSS paragraph above.

2. Tripping of a DC breaker shall initiate tripping of the remote active breaker feeding the same section.

3. Provide two types of transfer trip:
   a. Automatically resettable (Device 85): Automatic resetting shall be controlled by the load measure reclose relay and occurs on di/dt faults.
   b. Manual resetting (Device 85L): It shall trip the DC lockout relay (Device 186H) in both the originating and receiving substations, and is required for DC instantaneous over-current, frame faults, rail-to-earth potential faults, incomplete sequence faults.

E. Transfer Trip Function, Initiated by ETS and SSS

1. Wire Emergency Trip Station (ETS) pushbuttons to provide a loop circuit of series wired contacts that shall energize a summary relay.

2. Interruption of the series circuit shall cause the substation and adjacent substations to shut down as follows:
   a. Originating substation:
      1) AC main breaker: Trips and locks out.
      2) DC main breaker: Trips and locks out.
      3) DC feeder breakers: Trip and lock out.
   b. Adjacent active substations are shut down by transfer trip from the originating substation, as follows:
      1) All DC feeder breakers feeding the same OCS section: Trip and lock out.
      2) If an adjacent substation is off-line and equipped with by pass switches that are closed, the transfer trip signal continues to the next adjacent substation that is energized and will Trip and Lock out all DC feeder breakers feeding the same OCS section.

3. Wire Substation Shutdown Station (SSS) with the same functions as ETS, except SSS shall not transfer trip adjacent substations.

2.14 FABRICATION

A. LCMSs shall be wired in accordance with Section 26 05 19, Low-Voltage Conductors and Cables, using type SIS wire, and wire markers.
B. The HMI and ancillary devices shall be flush mounted in the door of the main DC switchgear enclosure or negative cubicle.

C. Auxiliary relays, duct and terminal strips shall be located on a removable panel.

D. DIN rail mounted terminals shall be used, similar to the arrangement in existing Central Link and University Link TPSSs, unless otherwise approved by Sound Transit.

2.15 SOURCE QUALITY CONTROL

A. Tests and Inspections: IEDs or ICs used in place of ANSI devices shall be factory design tested and factory production tested in accordance with Section 34 21 16.11, Traction Power Substation Testing, for the ANSI device, or devices they are replacing.

PART 3 - EXECUTION

3.01 INSTALLATION

A. LCMS hardware shall be identical and interchangeable between TPSSs, including wire numbering and marking conventions.

B. All interconnecting wiring shall be minimum No. 14 AWG type SIS rated at 600 Vac, or multiple conductor, low voltage cable in accordance with Section 26 05 19, Low-Voltage Conductors and Cables.

C. Provide an interior Fiber Distribution Panel in each TPSS, and a Communication Distribution Cabinet on the exterior of TPSS's where indicated on Drawings.

D. Provide and terminate fiber optic cable for SCADA at the Fiber Distribution Panel.

3.02 FIELD QUALITY CONTROL

A. Field Tests and Inspections: Test the following in accordance with Section 34 21 16.11, Traction Power Substation Testing:

1. LCMS.

2. IEDs and ICs.

3. Application software.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Components and materials that are part of the traction power equipment, including the following:
   a. Electrical insulating laminate.
   b. Electrical varnish for cut surfaces of insulating material.
   c. ETS/SSS buttons and enclosures.
   d. Knox box.
   e. Blue light.
   f. Fire extinguisher.
   g. AC/Dc breaker test station.
   h. Mobile work station.
   i. Station FCC ETS Cabinet, enclosure, controls, indications, signage.
   j. Communications Interface Cabinets.
   k. Sump pump, oil sensor, controls, piping, and accessories


3. Placards and signage.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. National Fire Protection Association (NFPA):
   a. NFPA 70 - National Electrical Code (NEC).

1.03 ADMINISTRATIVE REQUIREMENTS

A. Scheduling: Arrange to ship batteries directly from the manufacturer immediately prior to installation. Batteries older than 3 months are not acceptable.
1.04 SUBMITTALS

A. Product Data: For each product indicated, but not limited to the following:

1. Electrical insulating laminate.
2. Electrical varnish for cut surfaces of insulating material.
3. ETS/SSS buttons and enclosures.
4. Knox box.
5. Blue light.
6. Fire extinguisher.
7. AC/Dc breaker test station.
8. Mobile work station.
9. Station FCC ETS Cabinet, enclosure, controls, indications, signage.
10. Qualifications of Field Service Engineer.
11. Communication Interface Cabinet.
12. Sump pump, accessories, piping and hardware, controls and indications, documentation to establish service proven history, including details of application history, including number of units in operation and length of time in service.

B. Shop Drawings:

1. Seismic Bracing and Anchorage Plan:
   a. Submit in accordance with seismic submittal requirements in Section 26 05 00, Common Work Results for Electrical.
   b. Include bracing and anchorage for built-in-place substations, pre-fabricated substations, and circuit breakers in cross passage.
   c. Plan shall demonstrate the suitability of the proposed anchorage and bracing.
   d. Plan shall address anchorage of the following equipment, as applicable:
      1) AC switchgear.
      2) Traction power transformer.
      3) Rectifier.
      4) Dc Switchgear, including method of electrical isolation.
      5) Dc Disconnect Switches.
      6) Conduit racks.
      7) Cable tray.
8) Battery and battery rack.
9) Circuit breakers in cross passage.
10) Communications, HMI & control cabinets.
11) Mechanical equipment, including Sump Pump.

2. Raceway layout drawings and mounting details.

   a. Submit for each built-in-place facility if installations differ.
   b. Submit for pre-fabricated substations.
   c. Provide plan view showing perimeter ground bus, equipment, and ground connections.
   d. Provide elevations of each wall showing height of perimeter ground bus and connections to equipment.

4. Station Fire Control Center (FCC), Emergency Trip Station (ETS) buttons schematic, wiring and installation drawings.

5. Sump pump installation drawings

C. Pre-Fabricated Substation Setting Plan.

D. Certifications: Contractor Certified built-in-place traction power facility floor plans for all equipment to be placed in TPSS rooms.

E. Samples: Samples for placards and signage.

F. Manufacturer’s Instructions: Shipping, Handling, and Storage Plan for TPSS Equipment.

G. Built-in-Place Substations: Submit a Shipping, Handling and Storage Plan, including the following:
   1. The number of individual pre-wired units to be shipped from the factory.
   2. Handling and shipping preparations for each unit.
   3. Storage plans for equipment and other material not immediately installed in its permanent location upon arrival.
   4. Unloading setting and inspection procedures for each unit upon arrival at the site.

H. Pre-fabricated Substations: Submit a Setting Plan, including the following:
   1. Drawing showing placement of crane and truck in relation to substation foundation.
   2. Written description of steps to be taken to pick and set substation.
   3. Approved traffic control plan from the City, if a plan is required.
I. Operation and Maintenance Data: Operation and maintenance data including product data and bill of materials for components specified in this Section.

1.05 QUALITY ASSURANCE

A. Equipment Manufacturer’s Field Service Engineer Qualifications:
   1. Installation Field Service Engineer shall have 10 years experience commissioning rail transit traction power substations of the specified type, size and equipment characteristics.
   2. Proposed engineer’s resume to be submitted to Resident Engineer for approval.

1.06 DELIVERY, STORAGE AND HANDLING

A. Obtain permission from Resident Engineer prior to shipping each Traction Power Substation or other traction power equipment to the site.

B. Ship and store equipment and material intended for use on this Contract such that damage or reduction in life is prevented.

C. Protect equipment and material and maintain in new condition throughout the Contract period until acceptance by Sound Transit.
   1. Protect stored material subject to corrosion with waterproof covers or coatings. Materials and equipment shall be stored under cover and off the floor or ground.
   2. Seal insulated cable ends and store in a dry location to prevent the entry of moisture into the cable conductors.
   3. Store equipment with all ports, covers and other enclosure openings closed to prevent ingestion of dirt or moisture and keep dry and free from condensation.
   4. Take special care with the storage of power transformers, switchgear and other components which shall be stored indoors, in a dry, heated, approved location.
   5. Handle or store material with special handling or storage requirements according to the manufacturer’s requirements.

D. Equipment that has become wet or damp shall be rejected by Sound Transit as defective.

E. Identification:
   1. Clearly mark material with a defined life expectancy with the expiration date. Material shall not be used beyond the expiration date.
   2. Clearly mark material and store with appropriate nomenclature to prevent misapplication.
   3. Mark and promptly remove from the jobsite rejected or used material, or material which is not in conformance with the Contract requirements.

1.07 FIELD/SITE CONDITIONS

A. Temporary Power Requirements:
1. After equipment installation, protect equipment from damage from moisture by maintaining heat within each space, or within each piece of substation equipment.

2. Arrange temporary electrical service as needed to each of the spaces and either energize the electrical panels and heaters in the spaces, or provide temporary service equipment sufficient to power temporary heaters.

3. Maintain the temporary electrical service in operation until the permanent electrical service is energized and there has been Final Acceptance by Sound Transit.

4. All cost of temporary power shall be at the cost of the Contractor.

B. Built-in-Place Traction Power Facility: Room lighting, emergency lighting, wall receptacles, and HVAC are provided under other specification sections. Smoke and fire detection system are provided under other specifications sections. Interfaces with those systems to be coordinated by the contractor.

PART 2 - PRODUCTS

2.01 INSULATING MATERIALS

A. Wherever “electrical insulating laminates”, “laminates”, “Glastic barrier” or “Glastic pad” are called out in the Contract Documents, it shall conform to the following:

1. Basis of Design: Röchling Glastic Composites, Glastic 1494 or approved equal.

2. Thickness: 1/4 inch, unless indicated otherwise.

B. Electrically Insulated Floor Covering: Specified in Section 09 67 25, Dielectric Epoxy Flooring.

C. Sealing material for cut edges of electrical insulating laminate: Electrical varnish such as Ashland Chemical, Hetrolac, or other product recommended for use with Glastic.

D. Prohibited Insulating Materials:

1. Electrical insulating paper, also called “fish paper”.

2. Electrical tape of any type.

2.02 COMPONENTS

A. ETS/SSS Buttons: Heavy duty, industrial grade, pushbutton operator and contact block, rated for the load, large mushroom head, red, with protective cover or enclosure to prevent inadvertent activation.

1. Provide buttons with locking mechanism that mechanically locks upon activation.

2. Activated buttons shall place standing trip signal to related breakers until buttons are manually reset.


D. Knox Box With Lock: 6 inches by 6 inches by 4 inches. Obtain keying requirements from Local Fire Department.

E. Blue Light: 12 W LED, vandal proof lens and suitable for wet locations.

F. Wiring Devices: See Section 26 05 00, Common Work Results for Electrical.

G. Ground Bus: In accordance with bus bar requirements in Section 26 05 26, Grounding and Bonding, 1/4-inch thick, silver plated, width as specified below in Part 3.

H. Fire Extinguisher: 20 pound, CO₂.

I. Eye Wash Station: See Section 22 45 19, Self-Contained Eyewash Equipment.

J. AC/Dc Breaker Test Station:
   1. Capable of tripping AC or dc breaker.
   2. Wall mounted unit with umbilical cord for connecting to breaker.
   3. Provide strain relief where cord connects to cabinet.
   4. Provide means to conveniently stow umbilical cord when not in use.
   5. Separate umbilical cords may be provided for AC and dc breakers.
   6. Provide indicating lights of "OPENED" and "CLOSED"

K. Mobile Workstation:
   1. Basis of Design: Rubbermaid TradeMaster, Model 4533-88 or approved equal.
   2. Description: Caster-equipped non-metallic tool cabinet topped with a work surface suitable to hold drawings, tools, or portable test instruments.
   3. Construction:
      a. Heavy-duty plastic.
   4. Features:
      a. Wheels: Four 5-inch casters.
      b. Drawers: Four, with ball bearing door slides.
      c. Cabinet with adjustable shelf.
      d. Built-in drawer lock.
      e. Provide one workstation per substation.
   5. Nominal Dimensions:
      a. Width: 49 inches.
b. Depth: 26 inches.

c. Height: Nominal 38 inches.

2.03 STATION FIRE COMMAND CENTER (FCC) OR FIRE CONTROL ROOM (FCR) ETS PANEL

A. Enclosure: As indicated on Contract Drawings.

B. Controls and Indications:

1. Provide control power indication light on ETS panel. The light indicates the presence of ETS button control power. If the ETS is connected to the TPSS equipment by a communications circuit, provide a visual indication that the communications circuit is functional. Local power for the ETS, if needed, shall be provided by the station or signals UPS.

2. Provide two buttons to de-energize tracks respectively.

C. Function: Traction power is re-energized remotely from LCC (Light Rail Control Center) after ETS buttons are manually reset.

D. Signage: Provide “SHUT DOWN XB TRACTION POWER” sign above each button, as appropriate.

2.04 EXTERIOR COMMUNICATIONS INTERFACE CABINET

A. Cabinet Enclosure Requirements:

1. Dimensions: 2 feet W by 1 foot D by 3 feet H.

2. Rating: NEMA 3R.

3. Construction: 14 gage steel, seams continuously welded and ground smooth; no holes or knockouts except in rear for access to inside of TPSS, wallmountable.

4. Color: Same as the TPSS.

B. Cabinet Door.

1. Provide forced-entry-resistant doors with a three-point lock.

2. Door in closed position shall not interfere with any installed equipment, wiring, or rack frame.

3. Provide full access to all Contractor-provided equipment.

4. Equip doors with a device that restrains the doors in the open position.

5. Locks: Door handle shall accept a padlock. Locks shall be keyed alike.

6. Seal locking device to prevent water intrusion into cabinet.

7. Provide five master keys to Resident Engineer.

C. Interior Components:

1. Rack: Minimum 2 ft-9 in high, to accept standard 19-inch rack-mountable equipment:
2. In addition to required communication equipment, provide the following:
   a. Ground Bar.
   b. Door activated interior light.
   c. Door switch for operation of lighting.
   d. Intrusion alarm door switch.
   e. Drawing pocket.
   f. Grounding straps from door to cabinet and swing rack to cabinet.
   g. Mounting brackets for DIN rails.
   h. Equipment shelves, mounting panels, brackets, and supports.
   i. Wire management guide brackets.
   j. Supervised power outlet strips.
   k. Terminal strips and patch panels.
   l. 120 Vac utility receptacle outlet.

2.05 SUMP PUMP SYSTEM

A. General Requirements:
   1. The control system of the sump pump shall allow water to be automatically pumped from the pit without danger of ejecting potentially harmful oily substances into the sewer.
   2. TPSS sumps with a gravity drainage connection do not require a sump pump.

B. Sump Pump:
   1. Type: Industrial/commercial, 120/240 Vac, with pump base, screen, column and stainless steel float(s).
   2. Size: Minimum 1 HP.
   3. Flow volume: Maximum 60 GPM.
   4. Pumps for all TPSS to be the same.

C. Control System:
   1. Description:
      a. The control system shall be capable of controlling the sump pump and have a proven record of reliable service.
      b. The control system shall be compatible with a variety of sump pump and valve manufactures.
3. Indicator Lights: LED, to indicate oil alarm, high motor current alarm, power to system, pump running, and high water alarm.

4. Alarms: All alarm indications shall also annunciate with an audible alarm.

5. Remote Monitoring: Indicators shall have capabilities for remote monitoring connections for data delivery to SCADA.

D. Piping:
   1. Discharge Piping: Schedule 80 PVC.
   3. Discharge Piping Supports: Stainless steel.

E. Accessories:
   1. Check valve: Full flow PVC.
   2. High water alarm: 120 Vac control; dual float switch, local and remote indicators, in NEMA 3R enclosure, similar to SJE-Rhombus model TADUO-01H, or approved equal.

2.06 PLACARDS AND SIGNAGE

A. All exterior signs shall be waterproof and UV protected.

B. Provide signage on all TPSS doors facing outside that reads DANGER HIGH VOLTAGE-AUTHORIZED ENTRY ONLY.

C. Provide information placards or signs containing information on de-energizing the high-voltage electrical rooms, location of the disconnecting switches, and phone numbers for the appropriate personnel who are required to disconnect the power.

D. Provide signage to clearly identify the Traction Power Substation Emergency Trip Stations (ETS), and information placards or signs containing information describing the sections of track that the ETS de-energizes, and contact information for Link Control at the adjacent ETEL serving the ETS.

E. Provide TPSS identification sign with number on each TPSS exterior door.

2.07 FACTORY ASSEMBLY

A. Requirements for installation in Part 3 apply to factory assembly of pre-fabricated substations, except where requirements are specific to built-in-place substations.

PART 3 - EXECUTION

3.01 INSTALLATION - GENERAL

A. Installation work shall not start until anchorage, raceway, and wiring drawings have been approved by Sound Transit.

B. TES Substation Equipment Manufacturer’s Field Service Engineer:
1. Perform Work under this Section under the direct supervision of the TES substation equipment manufacturer’s Field Service Engineer.

2. Engineer shall be onsite to coordinate and direct installation from floor and wall insulation to testing and start-up of each substation.

C. Equipment shall be installed in accordance with manufacturer’s instructions and these Specifications.

D. Locate and install equipment in accordance with Contract Documents and approved shop drawings.

E. Make minor changes in location of exposed conduits, cable tray, or equipment prior to installation as directed by Resident Engineer, at no additional cost to Sound Transit.

F. Prohibited Installation Methods:

1. Open wiring of any kind, except as specifically authorized by Sound Transit.

2. Support of conductors by metal channel.

3. Support of conductors from conduits, equipment or building framing using nylon wire ties.

4. Wiring gutter and wireways shall not be used for either power or control wiring.

3.02 INSTALLATION OF ELECTRICALLY INSULATING MATERIALS

A. The dc switchgear shall be completely electrically and physically isolated and insulated from the walls by electrical insulating laminate.

1. Laminate shall be full height.

2. For walls where the clearance between dc switchgear and walls is 6 feet or greater, electrical insulating laminate will not be required on those walls.

3. Fasten the laminate in place using non-conductive and non-metallic fasteners, in accordance with the manufacturer's instructions.

B. Insulate all metallic surfaces within 6 feet of rectifier and dc switchgear.

C. Provide a full and continuous piece of laminate to isolate the rectifier transformer from the dc switchgear.

1. Extend barrier into the room at full height, as shown on the Contract Drawings.

2. Reinforce the edge with a non-metallic angle or channel fastened to the floor and ceiling for stiffness.

D. Fasten a continuous piece of laminate to the ceiling over the arc chutes of the dc breakers if conductive surfaces are within 3 feet of top of dc switchgear.

E. Seal cut surfaces of electrical insulating laminate with electrical varnish.

3.03 INSTALLATION OF DIELECTRIC EPOXY FLOORING

A. Refer to Section 09 67 25, Dielectric Epoxy Flooring.
3.04 INSTALLATION OF TPSS EQUIPMENT

A. Verify that rooms and premises are clean, warm, and dry.

B. Test installation of the floor and wall insulation as required by Section 34 21 16.11, Traction Power Substation Testing, prior to installation of equipment.

C. Protect the floor and wall insulation from damage during equipment installation.

D. Install equipment plumb, level, in a workmanlike manner, and square with building lines.

E. Seismic Requirements:
   1. Refer to Section 26 05 00, Common Work Results for Electrical, for seismic requirements.
   2. Brace equipment and raceways against earthquakes by securely fastening in place.
   3. Brace freestanding equipment such as switchgear at the top to prevent movement and fasten at the bottom to prevent sliding or walking.
   4. Securely fasten floor-mounted transformers and AC switchgear to the floor using concrete expansion anchors or nuts and bolts for prefabricated substations.
   5. Securely fasten dc switchgear to the floor but take great care to maintain electrical isolation from the building structure and other equipment through the use of dielectric spacers or shims used in conjunction with the fasteners, hardware and insulated flooring.
   6. Support conduit racks and cable trays laterally using braces fabricated from channel and fittings.
      a. Supports shall be sufficient to withstand the seismic load.
      b. Locate lateral supports within 2 feet of each bend or tray dropout and space no greater than 10 feet apart.

3.05 INSTALLATION OF TPSS GROUNDING

A. Connect grounding pigtails from grounding grid to the grounding pads specified in Section 34 21 16.17, Prefabricated Traction Power Substation Building, and to the substation interior perimeter ground bus.

B. Interior Perimeter Ground Bus:
   1. Provide 2-inch wide copper ground bus around entire perimeter of substation room.
      a. Mount on metallic stand offs.
      b. Install at 18 inches above finished floor where there are no obstructions, and up to 8 feet above finished floor to avoid equipment or doorways.
      c. Connect grounds furnished and installed by others in accordance with Section 26 05 26, Grounding and Bonding.
2. Provide 1-inch wide copper ground bus from panelboards and other electrical equipment within 8 feet of ground bus, including panelboards and equipment installed by others, to perimeter ground bus.

3.06 INSTALLATION OF TRACTION POWER TRANSFORMER AND AUXILIARY POWER TRANSFORMER

A. Locate and wire Traction Power Transformer and the Auxiliary Power Transformer as shown on Contract Drawings, or as otherwise approved by Sound Transit.

B. Make grounding connections to transformer frames and system neutrals as required by National Electrical Code and transformer manufacturer.

C. Mount transformers on vibration isolating pads.

D. Keep secondary feeders from TPSS Auxiliary Power Transformer to ac panelboards separate, partitioned and barriered from high-voltage conductors, and install in conduit.

E. Provide conduit and wiring for the Transformer Temperature Monitor in conduits or cable tray. The size of conduit, and type and number of conductors shall be in accordance with the requirements for wiring and the actual monitor provided, as approved by Sound Transit.

3.07 INSTALLATION OF AC AND DC SWITCHGEAR, AND RECTIFIER

A. The installation of the ac and dc switchgear, rectifier and transformer enclosure partitions, shall be in accordance with the approved shop drawings.

B. Completely insulate rectifier from ground and from the traction power transformer and the ac switchgear.
   1. Insulate and isolate rectifier from the floor using an epoxy floor covering in accordance with Section 09 67 25, Dielectric Epoxy Flooring.
   2. Insulate and isolate rectifier from the transformer using electrically laminate.

3.08 INSTALLATION OF CONTROL POWER SYSTEM

A. Provide complete control power system in accordance with Section 34 21 16.21, TPSS – Control Power, the Contract Drawings, and the approved shop drawings.

B. System consists of the following components:
   1. Battery
   2. Battery Charger
   3. Panelboard
   4. Disconnecting switch

C. Verify NFPA 70 required electrical clearances prior to installation of panelboards.

D. Interconnecting wiring shall be 600 Vac installed in rigid metal conduit in accordance with these Specifications.

E. Verify prior to installation that batteries are less than 3 months old.
F. Provide 1/4-inch glastic barrier around control battery.

3.09 INSTALLATION OF AC PANELBOARD WIRING AND CIRCUIT BREAKERS

A. Built-in-place substations: Ac panelboard and feeder is provided under separate specification sections. Refer to the Contract Drawings. Provide additional breakers as needed, subject to Sound Transit approval.

B. Prefabricated Substations: Provide power cables from the TPSS auxiliary power transformer to the ac panelboard as required. Install wiring in conduit or cable tray in accordance with the Specifications, and as approved by Sound Transit.

C. Provide conduit or cable tray and power wiring between the ac panelboard and substation equipment.

3.10 INSTALLATION OF CONDUIT AND BOXES

A. Provide conduit and boxes within the traction power substations in accordance with Section 26 05 33, Raceways and Boxes.

B. Provide conduit supports and conduit racks using channels and clamps in accordance with Section 26 05 29, Hangers and Supports for Electrical Systems.

3.11 INSTALLATION OF CABLE TRAY

A. Provide fiberglass cable tray, where required, in accordance with Section 26 05 33, Raceways and Boxes.

B. Support cable tray in accordance with Section 26 05 29, Hangers and Supports for Electrical Systems.

C. Where cable tray is used, provide separators for power and 125 Vdc control wiring.

3.12 INSTALLATION OF CONDUCTORS

A. General:

1. Install wire and cable in accordance with Section 26 05 00, Common Work Results for Systems Conductors and Cable.

2. Install wiring in accordance with approved manufacturer’s wiring diagrams and schematics.

3. Install wiring only after equipment is set in place and anchored.

4. Wiring shall be housed within equipment or installed in cable tray or raceway using a type TC cable or individual power cables.

B. Conductor Type Requirements:

1. Provide 2.4 kV medium-voltage single conductor cables for TES system feeder conductors in accordance with Section 34 21 28, Medium-Voltage Conductors and Cables.

2. Provide 600 Vac single conductor wire for low-voltage panelboard feeders, low-voltage ac circuits, and 125 Vdc circuits in accordance with Section 26 05 19, Low-Voltage Conductors and Cables.
3. All 125 Vdc interconnecting wiring shall be in multi-conductor type TC cable inside the Substation. Single conductors (not in a cable) shall not be used for interconnecting power or control wiring.

4. All 125 Vdc control wiring from the emergency shutdown stations shall be wired using type TC 600 V multi-conductor cable either in cable tray or conduit.

5. Single conductors (not in a cable) shall be used only in conduit.

3.13 INSTALLATION OF SUBSTATION SUB-SYSTEMS

A. Emergency Trip Stations on the Exterior of Substation:
1. Provide single Emergency Trip Station (ETS) pushbutton on the exterior of each TPSS in the specified exterior enclosure, as indicated on Contract Drawings.
2. Activation of the pushbutton de-energizes both tracks by transfer tripping adjacent substations, as specified in Section 34 21 16.23, TE Substation LCMS and IED.
3. Traction power is manually restored from inside the TPSS after activation of ETS button.
4. See Part 2, Article titled “Station Fire Control Center ETS Panel” for FCC ETS requirements.

B. Substation Shutdown Station:
1. Provide Substation Shutdown Station (SSS) pushbuttons on the interior of each substation near each entry door.
2. Activation of the pushbutton de-energizes rectifiers and rectifier transformers in the TPSS, and trips local dc feeder breakers. It does not send a transfer trip signal.

C. LCMS: The low-voltage alarms, including the smoke alarm and intrusion alarm, shall be wired directly back to the LCMS of the Substation using #14 AWG 600 V conductors in conduit.

D. Security Card Readers: Refer to Section 28 13 01, Access Control System, for requirements.

E. Knox Box:
1. Mount below the exterior ETS enclosure, or as directed by Resident Engineer.
2. Provide with key to ETS enclosure for access by Fire Department. Obtain Knox Box keying requirements from Fire Department.

F. Blue Light Station: Mount on exterior of substation as shown on Contract Drawings. Connect to ac circuit such that it will remain energized at all times.

G. Ac/Dc Breaker Test Station:
1. Provide at substations.
2. Wall mount, as indicated on Contract Drawings.
3.14 INSTALLATION OF STATION FIRE CONTROL CENTER ETS PANEL
   A. Provide ETS panel at elevated and underground station’s FCC or fire control panel locations.

3.15 INSTALLATION OF EXTERIOR COMMUNICATIONS INTERFACE CABINET
   A. Provide a communications case per the Exterior Communications Interface Cabinet article, above.
   B. Wall mount as indicated on Contract Drawings such that it is accessible without going into the TPSS.

3.16 INSTALLATION OF SUMP PUMP SYSTEM
   A. Install sump pump in Substation vault sump pit. Secure per approved shop drawings.
   B. Wire to ac power panel with GRS conduit.
   C. Install and connect 2-inch discharge piping from pump to drainage system.
   D. Provide check valve to prevent backflow.
   E. Install alarms to LCMS and wire to SCADA system.

3.17 FIELD QUALITY CONTROL
   A. Electrical Inspections:
      1. Sound Transit may observe all electrical inspections. Electrical inspections shall be scheduled a minimum of 7 Days in advance with Sound Transit and the State or local Electrical Inspectors.
      2. All corrections directed by electrical inspectors shall be performed by Contractor at no additional cost to Sound Transit.

END OF SECTION
SECTION 34 21 16.26
TRANSFORMER RECTIFIER UNIT

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
1. Traction power transformer and rectifiers, which are referred to in this Section as the "Transformer Rectifier Unit" for the Traction Power Substation.

1.02 REFERENCES
A. Abbreviations and Acronyms:
1. TPSS: Traction Power Substation.
2. TPT: Traction Power Transformer.
3. VPI: Vacuum Pressure Impregnation.

B. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.
1. National Electrical Manufacturers Association (NEMA):
   a. NEMA TR 1 - Transformers, Regulators and Reactors.
   b. NEMA SG 6 - Power Switching Equipment.
3. Institute of Electrical & Electronics Engineers (IEEE):
   b. IEEE 1653.2 - Standard for Uncontrolled Traction Power Rectifiers for Substation Applications Up to 1500 V DC Nominal Output.
   c. IEEE C37.20.3 - Standard for Metal-Enclosed Interrupter Switchgear (1 kV-38 kV).
   d. IEEE C57.12.01 - Standard for General Requirements for Dry-Type Distribution and Power Transformers.
   e. IEEE C57.12.91 - Standard Test Code for Dry-Type Distribution and Power Transformers.

1.03 SUBMITTALS
A. Product Data: Submit the following in accordance with the Contract Documents:
1. Manufacturer's product descriptions and catalog data.
2. Bus and bus insulators.
3. Transformer winding insulation system.
4. Relays, protective devices, control switches, over temperature devices and failed diode indication device.
5. Information concerning design and application ratings.
6. Information concerning service, performance and reliability.
7. Documents confirming the substation system rating.

B. Shop Drawings: Submit the following:

1. Manufacturer’s arrangement and outline dimensions for each item of transformer-rectifier unit.
2. Detail drawings for each item of transformer-rectifier unit, including interphase transformer and transformer insulation system details.
3. Transformer and power rectifier circuit diagrams.
4. Wiring, schematic, and connection diagrams.
5. Transformer nameplate drawing with nameplate details.
6. Rectifier nameplate drawing.
7. Transformer outline drawing showing dimensions, front, back and side elevations of enclosure, overall dimensions, lifting lugs, and transformer data, including weight, impedance, and primary and secondary BIL.
8. Transformer mounting and vibration isolation details.
9. Transformer primary and secondary busing arrangements showing bus construction details and bill of materials.
10. Transformer temperature monitor/protection device schematic and wiring diagram including the location of the temperature sensor.
11. Rectifier monitoring and protection schematic and wiring diagram.
12. Transformer tap changer arrangement details.
13. Transformer enclosure, door hinge and latch details.
14. Rectifier enclosure and door latch details.

C. Engineering Calculations:

1. Transformer design calculations, including hottest spot temperature rise in accordance with IEEE C57.12.01.
2. Transformer calculation of winding temperature during a short circuit in accordance with IEEE C57.12.01.
4. Transformer design optimization calculations.

5. Proof the transformer rectifier design and construction conforms to IEEE519.

D. Post-Manufacturing: Submit the following upon completion of transformer manufacture:

1. Updated load and no load losses schedule with measured values in accordance with Table 1.

2. Updated present worth of energy losses over 30 years with measured values.

E. Test and Evaluation Reports: Submit test procedures and test reports in accordance with Section 34 21 16.11, Traction Power Substation Testing.

F. Operation and Maintenance Data:

1. Submittal information identified above.

2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.

3. Wiring diagram.

4. Recommended list of spare parts.

5. Diagram showing recommended safety grounding during maintenance.

1.04 TOOLS

A. Provide one set of tools to remove or install diodes, diode fuses, and hardware for each substation.

1.05 QUALITY ASSURANCE

A. Traction Power Transformer shall be UL labeled or shall be furnished with a Field Evaluation label in accordance with Section 34 21 10, Traction Electrification System General Requirements.

B. Rectifier shall be UL labeled or shall be furnished with a Field Evaluation label in accordance with Section 34 21 10, Traction Electrification System General Requirements.

PART 2 - PRODUCTS

2.01 TRANSFORMER RECTIFIER UNIT

A. Transformer rectifier unit consists of a separate traction power transformer and a rectifier, as shown on Contract Drawings.

1. Both transformer and rectifier shall be identical or interchangeable or approved equal to ST existing TPSS Traction Power Transformer Rectifier Unit.

2. Provide the unit complete with auxiliaries, controls, wireways, interconnecting ac and dc buses, enclosures and necessary hardware, wiring and devices from the high-voltage side of the transformer to the dc bus connections at the dc switchgear and negative enclosure.

3. Except as otherwise specified, the transformer-rectifier shall conform to IEEE C57.12.01, C57.12.91, 519, and 1653.2, and NEMA SG 6, and TR 1.
4. Transformer rectifier unit shall convert Medium Voltage (MV), 60 Hz AC, three-phase, three-conductor primary power to 1,500 Vdc at 100 percent of full load.

5. The transformer-rectifier unit shall receive ac power from the MV AC metal clad switchgear.

6. Dc output of the transformer-rectifier unit shall feed the metal enclosed DC switchgear that controls and protects the power supply to the Overhead Contact System.

7. Transformer-rectifier unit shall be rated as shown on Contract Drawings, measured at 1,500 Vdc at the output terminals.

8. Transformer-rectifier shall be 12-pulse, double-way, in accordance with IEEE 1653.2, Circuit No. 31.

B. Design Loading Condition: Design the transformer rectifier unit to meet the duty cycle specified in IEEE 1653.2 for extra heavy traction service.

C. Efficiency: Overall efficiency of transformer-rectifier assembly shall be greater than 98 percent at its continuous rating.

D. Power Factor: Displacement power factor of transformer-rectifier assembly shall be 0.95 or greater from 25 percent to full load at rated ac voltage.

E. Regulation:

1. Voltage on the DC bus shall be within the following limits with the nominal AC voltage maintained at the transformer primary and the transformer set at the rated voltage tap:

   Output Dc Voltage (Volts)
### Transformer Rectifier Unit

#### Output Current Table

<table>
<thead>
<tr>
<th>Output Current</th>
<th>Maximum</th>
<th>Nominal</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>No (1 percent)</td>
<td>1,590</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 percent full load</td>
<td>1,506</td>
<td>1,500</td>
<td>1,494</td>
</tr>
<tr>
<td>150 percent full load</td>
<td>1,460</td>
<td>1,454</td>
<td>1,448</td>
</tr>
<tr>
<td>300 percent full load</td>
<td>1,332</td>
<td>1,320</td>
<td>1,308</td>
</tr>
<tr>
<td>450 percent full load</td>
<td>1,198</td>
<td>1,186</td>
<td>1,172</td>
</tr>
</tbody>
</table>

2. Resident Engineer may allow minor variations in regulation based upon submitted design curve.

**F. Dummy Load:**

1. Limit the no-load voltage to the value specified.
2. Provide a bleeder resistance dummy load, if required, to prevent excessive voltage rise at no-load.

**G. Provide protection against transient surge voltages on the DC side of the rectifier.**

**H. Short Circuit Ratings:**

1. Design transformer, including terminal connections and buswork, to withstand a full short circuit with shorted low-voltage terminals and rated voltage on the high-voltage terminals, in accordance with IEEE C57.12.01. The duration of the short-circuit current shall be minimum 1 second.

2. Design all parts of the rectifier unit, including the terminal connections and buswork, to withstand a maximum DC fault on the DC positive bus, without damage, for the period required for the back-up protection to operate and open the AC circuit breaker.

**I. Audible Sound:** 70 dBA measured 3 feet from assembly under the following conditions.

1. Interphase transformer included in transformer-rectifier assembly.
2. Traction power transformer in its enclosure with all panels bolted closed.
3. Traction power transformer energized simultaneously at rated input voltage and 150 percent full load current.
2.02 TRACTION POWER TRANSFORMER

A. Provide dry-type traction power transformer of VPI (Vacuum Pressure Impregnation) construction with the following characteristics:

1. Ventilated, self-cooled Class AA/FA, at the IEEE 1653.2 extra heavy traction service power duty cycle with cooling fans and thermostats for forced air-cooling.
   a. IEEE 1653.2 extra heavy traction service rating shall be achieved by self-cooled condition. Fans shall increase the ratings of traction power transformer by extra 33 percent without exceeding Average Temperature Rise and Maximum Hot-Spot Temperature Rise values shown below.
   b. Fans are controlled by 49 device and powered by 120 Vac.

2. Insulation Class: 220 degrees C class.

3. Temperature Rise: Limit winding hottest-spot temperature rise and average winding temperature rise to the values given in IEEE C57.12.01 for the specified insulation class.

4. The transformer shall not suffer any loss of life when operated at the specified duty cycle.

B. Select the transformer impedance to provide the rectifier output voltage specified.

C. Use bolted straps and stainless steel fasteners throughout. Tie wraps are prohibited.

D. Windings:

1. High-voltage and low-voltage windings shall be copper.

2. Windings shall not absorb moisture and shall be suitable for both storage and operation in adverse environments, including prolonged storage in 100 percent humidity at temperature from minus 30 degrees C to 40 degrees C.

3. High-Voltage Windings:
   a. Delta-connected.
   b. 110 kV BIL for 12.5kV and 150kV BIL for 27kV.

4. Low-Voltage Windings:
   a. Connected for 12-pulse rectification.
   b. 45 kV BIL

E. Taps:

1. Provide five full capacity taps on high-voltage windings:
   a. Two above rated voltage in 1.25 percent steps.
   b. Two below rated voltage in 2.5 percent steps.
   c. One at rated voltage.

2. Tap changing shall be by movable silver plated copper bus links for de-energized tap changing.
3. Taps shall be brought out the front of the transformer, not the top.

4. Insulate jumpers from the transformer taps to the tap changer board and primary bus and keep as short as possible so as not to interfere with access to the coils for maintenance.

5. Tap connections shall be accessible through the front hinged enclosure doors.

6. Identify tap connections so that the tap selected is clearly visible through the observation window.

7. Securely bolt the tap-changing bus links in position.

8. Design of links and connectors shall make it impossible to short out sections of windings, or to select taps outside the prescribed range, by incorrectly connecting the links.

F. Connections:

1. MV AC Switchgear: Connect the high-voltage side using cable or electrical grade copper bus with silver plated joints.

2. Rectifier: Connect the low voltage side using electrical grade copper bus with silver plated joints.

3. Provide a short length of copper braid on terminals of primary and secondary connections to the transformer terminals.

G. Supports:

   a. Insulators shall be rated for the line-to-line voltage application, free of imperfections.
   b. Insulators that have been re-touched with paint shall not be used.

2. Securely support the cable or bus from the transformer frame by electrical porcelain insulators.
   a. The support of the cable or the bus shall be sized for mechanical strength and ability to withstand a bolted fault without distortion.

H. Bus Bars:

1. Size:
   a. Size bus and supports for mechanical strength and ability to withstand a bolted fault without distortion, 1/4-inch by 2-inch minimum.
   b. Size bus for a current density of 750 A per square inch, or a maximum temperature of 90 degrees C at a 40 degree C ambient, whichever results in a larger size.

2. Connections: Use a minimum of two silicon-bronze bolted connections with Belleville washers for bolted connections on high and low ac and dc buses.

3. Bus:
a. AC bus from the secondary taps on the coil to the rectifier bus shall be sized for maximum loading for IEEE 1653.2 extra heavy traction service loading.

b. AC bus duct, if used, shall be mounted high enough above rectifier enclosure to allow adequate ventilation for rectifier heat to escape through the top of rectifier.

I. Maintainability:

1. Design transformer so that parts which require maintenance are readily accessible from the front and rear.

2. Ensure that bottom and top of coils are readily accessible for cleaning without removing buswork, panels, or obstructions of any kind.

J. Transformer Enclosure and Base:

1. Enclosure:

   a. Enclose transformer in a rigid, self-supporting and self-contained, electrically welded or bolted, indoor, steel enclosure.

   b. The structure shall be sufficiently rigid to withstand maximum transformer short circuit currents without deformation.

2. Doors:

   a. Provide convenient access doors on the front and rear of the section for normal maintenance and inspection. Rear doors are not required for prefabricated substations. Doors and panels are required on the exterior of the buildings.

   b. Latches: Equip each door with heavy duty latches to hold the door fully and securely closed.

   c. Hinges: Stainless steel heavy-duty type.

   d. Front Door: The entire front of the transformer shall open by padlockable, hinged double doors secured by three-point latches.

   e. Rear Door: The rear of the transformer shall be accessible by hinged double doors secured by three-point latches or removable panels. Both types shall be with stainless steel handles.

   f. Material/Construction: No. 11 gauge minimum sheet steel properly reinforced against distortion by suitable flanges and stiffening members.

   g. Window: Provide an ample sized, wired glass, gasketed observation window in the front hinged doors; position such that the tap connections are readily visible.

   h. Door Stops:

      1) Provide heavy-duty door stops to hold the door in the open position.

      2) Not easily bent if an attempt is made to close door without releasing door stop.
3. Ventilation Louvers: Design for maximum cooling from the bottom to top.

4. Transformer Base:
   a. Construct from structural steel members suitable for rolling or skidding in any direction.
   b. Make provisions for pulling along the centerlines perpendicular to each side.
   c. Provide jacking facilities at each of the four corners of the base to permit insertion of rollers between floor and base.
   d. Base construction shall firmly secure the core to prevent relative motion of the core during shipment, handling, or seismic shock.

5. Transformer Frame: Provide lifting hooks or eyes on the transformer frame with a safety factor of four to facilitate lifting the unit.

6. Transformer Mounting: Design to minimize vibration by using vibration isolation dampers.

7. Nameplate: Provide traction power transformer with a corrosion-resistant metal nameplate marked in accordance with IEEE C57.12.01, securely fastened to front of enclosure.


9. Finish: Transformer enclosure, front doors, rear doors, metallic frame, and supports shall be powder coated in accordance with Section 34 21 27, Metal Fabrication and Finishes.

K. AC Surge Arrester:
   1. Provide AC surge arresters on the traction power transformer primary side as close as possible to primary connections to transformer.
   2. Provide a separated space for AC surge arresters.
   3. The space shall be separated from other parts by rigid steel, self-supporting and self-contained, electrically welded or bolted.

2.03 TRANSFORMER DESIGN OPTIMIZATION

A. Optimize the transformer design and select appropriate materials to provide unit of the lowest possible life cycle cost:
   1. Definition of Life Cycle Cost: The sum of the procurement cost and the cost of energy losses over the equipment’s expected life.
   2. Calculate cost of energy losses as described in the following paragraphs.

B. Calculate Total Transformer Annual Energy Loss using Table 1, Transformer Loss Schedule, as follows:
   1. In Column 2 provide losses using the loads indicated in Column 1, which represent the fluctuating nature of traction loads.
2. Column 2 losses include power losses in the transformer windings, steel core, and busbars, and demand requirements of auxiliary equipment, such as cooling fans.

3. In Column 4 calculate the Transformer Annual Energy Loss by multiplying the losses in Column 2 by the time intervals provided in Column 3, which are the average predicted durations of each particular loss.

4. Total the numbers in Column 4 and enter in the box at the bottom of Table 1 for the Total Transformer Annual Energy Loss.

C. Calculation of Present Worth of Energy Losses:

1. Using the Total Transformer Annual Energy Loss as determined in Table 1, calculate the Present Worth of Energy Losses over a 30-year period from the equations shown in Table 2.

2. Insert the calculated Present Worth of Energy Losses into the Bid Form

**TABLE 1 - TRANSFORMER LOSS SCHEDULE**

<table>
<thead>
<tr>
<th>Description</th>
<th>Transformer Losses (kW)</th>
<th>Time Interval (Hours)</th>
<th>Transformer Annual Energy Losses (kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(0) No-load loss</td>
<td>4380</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>P(20) Total loss at 20 percent rated power - applicable to a load range of 1 percent to 40 percent of rated power</td>
<td>2190</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>P(60) Total loss at 60 percent rated power - applicable to a load range of 40</td>
<td>1314</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>P(100) Total loss at 100 percent rated power - applicable to a load range of 80</td>
<td>788</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>P(150) Total loss at 150 percent rated power - applicable to a load range of 120</td>
<td>88</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>P(220) Total loss at 220 percent rated power - applicable to a load range of 180</td>
<td>0</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>P(300) Total loss at 300 percent rated power - applicable to a load range of 260</td>
<td>0</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Total Transformer Annual Energy Loss E_L:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### TABLE 2 - PRESENT WORTH OF ENERGY LOSSES

<table>
<thead>
<tr>
<th>Transformer Type</th>
<th>Equation</th>
<th>Present Worth ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PW = N E L e (1/(1+i) + (1+k)/(1+i)^2 + ... + (1+k)^(n-1)/(1+i)^n)</td>
<td></td>
</tr>
</tbody>
</table>

**Total Power Supply System Present Worth of Losses Used in Bid Evaluations**

The equation in Table 2 uses the following notations:

<table>
<thead>
<tr>
<th>PW</th>
<th>Present Worth of Energy Losses</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>Number of transformer units</td>
</tr>
<tr>
<td>E_L</td>
<td>Total Transformer Annual Energy Losses (from Table 1)</td>
</tr>
<tr>
<td>e</td>
<td>Utility energy rate = 0.08 (Dollars/kWh)</td>
</tr>
<tr>
<td>i</td>
<td>Interest rate = 0.04 (4 percent)</td>
</tr>
<tr>
<td>k</td>
<td>Average energy cost escalation factor = 0.04</td>
</tr>
<tr>
<td>n</td>
<td>Economic life span of the equipment = 30 (years)</td>
</tr>
</tbody>
</table>

**D. Comparison of Calculated and Measured Present Worth of Energy Losses:**

1. Following transformer manufacture, measure the load and no-load losses for transformer, update Table 1 with the measured values, recalculate the Total Transformer Annual Energy Loss, and recalculate the Present Worth of Energy Losses, using Table 2.

2. In the event that the Measured Present Worth of Energy Losses exceeds the Calculated Present Worth of Energy Losses inserted in the Bid, Sound Transit will issue a unilateral deductive Change Order to deduct the excess energy costs Sound Transit will pay over the life of the transformer, as shown by the Measured Present Worth of Energy Losses.

**2.04 RECTIFIER**

**A. Type and Rating:**
1. Provide rectifier and interphase transformer as an integral part of the dc switchgear.

2. Rectifier assembly shall be constructed in accordance with IEEE C37.20.3, except as modified in this Section.

3. Rectifier shall be an operative assembly, consisting of silicon diodes, internal buses, terminals for connection to external power and control wiring or buses, shunts, base or bleeder load resistors, protective devices, control wiring, terminal blocks, compartments, cubicles and all other necessary accessories.

4. Rectifier shall be an integrated twelve-phase double way assembly with 12-pulse rectification as specified in this Section.

5. Rectifier shall be designed for extra heavy traction service as defined in IEEE 1653.2.

6. Rectifier assembly shall be identical, interchangeable or approved equal to existing East/ Northgate Link rectifier assemblies.

7. Rectifier unit shall be capable of supplying the following 100 percent continuous rating:
   a. DC Voltage: 1500.
   c. Kilowatts: As shown on Contract Drawings.
   d. DC Insulation: 3000-Volt Class.

8. All internal wires shall be rated at 5 kV.

B. Enclosure:

1. Mount rectifier assembly in a metal enclosed switchgear section or compartment.

2. The switchgear section shall be indoor, self-ventilated, metal enclosed structure with barriers, compartments, hinged doors as required by IEEE C37.20.3, except as modified in this Section.

3. Assemble enclosure with a rigid self-supporting structural steel framework.
   a. Structural members shall be of sufficient strength to support the buswork under short circuit conditions.
   b. Principal structural members shall be electrically welded or bolted together.
   c. Provide lifting eyes for lifting the rectifier unit from the top.
   d. The completed package shall be capable of being skidded or rolled any direction.
   e. Provide jacking lugs at each base corner.

4. Material: Construct compartment of not less than No. 11 gauge steel.

5. Doors:
a. Material: No. 11 gauge minimum sheet steel properly reinforced against distortion by suitable flanges and stiffening members.
b. Provide convenient access doors on the front and rear of the section for normal maintenance and inspection.
c. Latches: Equip each door with heavy-duty latches to hold the door fully and securely closed.
d. Hinges: Stainless steel heavy-duty type.
e. Provide viewing windows on doors such that condition of diode fuse indicators can be seen with doors closed.
f. Door Stops:
   1) Provide heavy duty door stops to hold the door in the open position.
   2) Not easily bent if an attempt is made to close door without releasing door stop.
g. Install front-mounted indicating and control devices without damaging the exposed finished surfaces.

6. Finish: Powder coat, in accordance with Section 34 21 27, Metal Fabrication and Finishes.

7. Color: Same as other substation enclosures.

8. Lighting: Provide interior lighting with switch on exterior of rectifier front door.

C. Bus and Connections:

1. Rectifier buses shall be made of rigid, high conductivity, electrical grade copper.
2. Buses shall be suitably braced between each other and to the enclosure with high-strength, non-tracking porcelain fiberglass insulators.
3. Buses shall be braced to safely withstand the available short-circuit current without damage to the bus or the switchgear.
4. Where an aluminum heat sink is used and a copper bus connection is required to the aluminum, apply oxide inhibitor to the joint.
5. Bus connections shall be bolted using a minimum of four bolts per joint.
   a. Wherever bolted together, the mating surfaces of copper buses shall be silver-plated.
   b. Bolted connections shall be made with Belleville washers.
6. Buses shall extend through the compartment walls to rear bus compartment and connect to the dc switchgear.
7. Rectifier section shall be designed as an integral part of the dc switchgear line up and shall be insulated from the ac and dc switchgear, substation grounds, or other enclosures.
8. Metal barriers, electrically bonded to the frame, shall be provided between dc positive and negative buses and terminal connections within the rectifier.

D. Dc Surge Arrester:
   1. Rectifier unit shall be equipped with dc surge arresters.
   2. The arresters shall limit the reverse voltage across rectifier silicon diodes to a value less than 75 percent of the peak-reverse-voltage rating of the diode by limiting the rise of the transient on the positive to negative bus.
   3. Ensure that arresters will fail in a safe manner. The failure/explosion of a dc surge arrester shall not cause live parts to be shorted to a ground/negative circuit.

E. Silicon Diodes:
   1. Silicon diodes shall be hermetically sealed and mounted on adequate heat sinks.
   2. Diodes shall be rated and tested in accordance with IEEE 1653.2.
   3. At 40 degrees C ambient, the rectifier shall be capable of carrying the extra heavy traction service loads specified in this Section with one paralleled diode removed from each phase arm without exceeding the safe junction temperature on the active diodes.
   4. Rectifier shall be able to withstand a bolted fault on the dc switchgear bus with one parallel diode removed from the phase arm without exceeding the safe diode junction temperature on the active diodes for the time it takes the ac breaker to clear the fault.
   5. Each diode shall be capable of withstanding, at its maximum operating temperature during blocking periods, repetitive voltages having a value 250 percent of its working peak reverse voltage without a permanent change in diode characteristics.
   6. Each individual diode shall have a peak inverse voltage rating equal to at least 266 percent of the applied peak inverse voltage at no load.
   7. Parallel stacks of diodes shall be electrically and geometrically similar and as symmetrical as practical to help balance the normal and surge electrical characteristics of each.
   8. Rectifier shall be designed to maintain current balance between parallel-connected diodes in each phase.
      a. The current for each diode of a parallel-connected stack shall not differ from its proportionate share of the total current by more than plus or minus 10 percent, between 50 percent and 150 percent of the rated capacity.
      b. This current balancing scheme shall hold individual diode currents within tolerances with one fuse in each phase arm open.
      c. Current balancing shall not be achieved by use of selectively matched diodes.
   9. Provide current limiting fuses with adequate interrupting capacity in series with each diode complete with a convenient visual fuse failure indication.
10. Blowing of one fuse in each phase arm shall not reduce overload capacity, nor reduce short-circuit capability.

11. Size fuses to the diode current rating; they shall not open or fail on any external dc fault or rated overload condition.
   a. Only the fuse connected to a failed (shorted) diode shall open.
   b. No other rectifier diodes or fuses shall fail or be damaged when one diode fails.

F. Fuses: 1500 V minimum, indicating type, drawout design.

G. Heating and Cooling System:

1. Rectifier shall be natural convection air-cooled.
   a. Circulation of ambient air shall do all necessary cooling at the extra heavy traction service loading specified.
   b. Cooling ducts shall not be used.

2. All rectifier cubicles shall be equipped with fans that are controlled by 26 device. The fans are for extra forced air cooling capacity in addition to the natural air cooling specified above.

3. Fans shall be powered by DC control power or 120 Vac isolation transformer specified in Section 34 21 16.25. Traction Power Substation Installation. Provide minimum 300 CFM fans.

H. Maintenance: Heat transfer surfaces and characteristics shall be designed for easy cleaning and to minimize accumulations of dust and other contaminants expected in the operating environment.

I. Provide mimic bus on the front of rectifier cubicles. See Section 3421 19.13, Medium-Voltage AC Circuit Breaker Switchgear.

J. In accordance with this Specification, voltages other than 125 Vdc control power are not permitted within the enclosure unless a specific requirement is stated in this Contract.

K. Nameplate:

1. Provide rectifier with a corrosion resistant metal nameplate containing the following information at a minimum:
   a. Name of Manufacturer.
   b. Descriptive Name.
   c. Type Designation.
   d. Serial Number(s).
   e. Output Rated Power.
   f. Output Rated Voltage.
   g. Output Rated Current.
   h. Overload Currents - Magnitude and Duration.
i. Weight.

2.05 PROTECTIVE DEVICES AND RELAYS FOR TRANSFORMER RECTIFIER UNIT

A. Coordinate protection to prevent false tripping or malfunction.

B. Provide the status of all protection devices on Local Centralized Monitoring System.

C. Supply an insulating dust cover for each internally-mounted device or the chamber that accommodates these devices.

D. Compartment: Mount control devices, relays and protective devices within the rectifier and transformer enclosure within a separate barriered compartment in compliance with IEEE C37.20.3.

E. Mount devices in location(s) not subject to heat from wire wound resistors in rectifier compartment:
   1. Devices shall be readily accessible without disassembling interior portions of the rectifier assembly.
   2. Control wiring shall be contained within the cubicle.
   3. Control wiring shall be barriered from and not intermixed with 1500 Vdc power wiring.
   4. No 1500 V devices shall be mounted in control compartment.

F. Provide the unit with heavy-duty dc-rated limit switches for door position contacts (Device 33):
   1. Locate on top and bottom of the rectifier and transformer enclosure front and rear doors.
   2. Shall trip and lock out the ac main breaker, open the positive main circuit breaker and annunci ate an opening of a door.
   3. Separate control compartments do not require Device 33.

G. Control Power:
   1. Power supply for all the protective devices and relays shall use 125 Vdc for auxiliary power system.
   2. 125 Vdc overcurrent control shall be via two-pole din-rail-mounted circuit breakers.

H. Provide transformer temperature monitor device and low voltage wiring:
   1. Transformer Temperature Monitor (TTM): Device 49:
      a. Shall be manufactured for the purpose.
      b. Shall have a service proven history.
   2. The TTM shall incorporate a hot spot winding temperature indicator:
      a. Location shall be that of the highest temperature reading obtained during system design testing.
3. TTM shall be provided with two-stage, electrically-independent contacts that close on rising temperatures for alarm (first stage) and tripping (second stage):
   a. First stage, 49T1, shall initiate a local and remote annunciation:
      1) The first stage shall initially be set at the temperature reached during the 2-hour heat run at 150 percent rated output, and annunciate when this temperature is reached.
      2) Cooling fans are started by the alarm, and stop when the temperature drops below alarm level.
   b. Second stage, 49T2, shall initiate a local and remote alarm and shall also trip and lock out the main ac breaker and open the main dc circuit breaker.
   c. Set Points:
      1) Temperature set points, T1 and T2, shall be field adjustable.
      2) Set points shall be factory-preset value when transformer is provided, as recommended by the manufacturer and approved by Resident Engineer.

4. Display temperature continuously on a digital display mounted on the surface of transformer panel:
   a. Accuracy: Within 1.5 percent of the full-scale reading.
   b. Scale: 0 to 999 Degrees C.
   c. Peak Temperature:
      1) Peak temperature shall be displayed when requested by the activation of a front panel mounted pushbutton.
      2) Peak temperature shall be resettable via a separate front panel mounted pushbutton.
      3) TTM shall store the peak temperature reached by the traction power transformer.

5. Enclosure: NEMA 1 enclosure for low voltage terminals:
   a. Cover: Hinged or screw cover.

6. Terminal Strips: Mount on the back panel.

7. Barriers: Provide where necessary to separate conductors with different voltage insulation ratings, such as thermocouple wiring and 125 Vdc control wiring.

8. Mounting: Securely mount enclosure to the transformer frame.
   a. Mount in a location readily accessible from the front as indicated, but not to restrict access to the transformer coils for maintenance.
   b. Do not mount the enclosure in removable panels.
9. Control Wiring:
   a. Provide interconnecting wiring to the substation LCMS as specified in Section 34 21 16.23, TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices.
   
   b. Control wiring in low-voltage sections shall be 600 V switchboard wire, as specified in Section 26 05 19, Low-Voltage Conductors and Cables, No. 14 AWG minimum, except for thermocouple wiring. Control wiring in dc sections shall be 2.4 kV rated.
   
   c. Design the control wiring for maximum IEEE 1653.2 ambient design temperature.
   
   d. Provide control wiring in galvanized GRS conduit securely strapped to the transformer frame or base, or to the enclosure if conduit does not obstruct removable panels or doors.
      
      1) If conduit must be secured to both frame or base and enclosure, insert a short section of liquidtight flexible metallic conduit for vibration isolation.
      
      2) Conductors may be unprotected for a maximum of 8 inches at the point of connection.

10. Contacts: Electrically separate and suitable for operation at 125 Vdc.

I. Provide the following protective devices for the rectifier; contacts on these devices shall be electrically separated:

1. Rectifier Over-temperature Device: Device 26R.
   
   a. Over temperature device shall be factory set, two stages.
   
   b. Device 26 R1 detects abnormal rise in diode heat sink or diode temperature and initiate alarm to local and remote annunciation. Rectifier fans are started by the alarm and stop when the temperature drops below alarm level.
   
   c. Set-point for the alarm shall be set during the factory design test to the level recorded during the two-hour 150 percent heat run.
   
   d. Device 26 R2 detects an additional rise in heat sink temperature and will trip and lock out the ac main breaker, open the main positive circuit breaker and shall annunciate locally and remotely.
   
   e. Devices shall be isolated from the bus voltage.

2. Frame fault protection for the rectifier: Device 64R provides high resistance frame fault protection for the rectifier cubicles.

3. Device 98-1 detects a failed diode and initiate alarm to local and remote annunciation.

4. Device 98-2 detects 2 diodes failed in a string and will trip and lock out the ac main breaker, open the main positive circuit breaker and shall annunciate locally and remotely.

5. Refer to Contract Drawings for additional protective devices.
2.06 FABRICATION
   A. Transformer rectifier unit shall be manufactured in accordance with the referenced standards and Section 26 05 00, Common Work Results for Electrical.

PART 3 - EXECUTION

3.01 INSTALLATION
   A. Transformer rectifier unit shall be installed in accordance with Section 34 21 16.25, Traction Power Substation Installation.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. Section includes:
      1. Rail Voltage Monitoring and Grounding System device in Traction Power Substation (TPSS).

1.02 DEFINITIONS
   A. Rail-to-Ground Voltage Value Definitions:
      2. Positive Voltage Value: Rail potential is higher than ground potential.
      3. Negative Voltage Value: Rail potential is lower than ground potential.
   B. Current Value Definition:
      1. Positive Current Value: Current flows from rail to ground.
      2. Negative Current Value: Current flows from ground to rail

1.03 SUBMITTALS
   A. Product Data:
      1. Manufacturer’s product descriptions and catalog data.
      2. Transducers, relays, thyristors and shorting switches.
      3. Information concerning design and application ratings.
      4. Proposed software.
      5. LCD display with proposed screen shots.
      6. Information concerning service, performance and reliability.
   B. Shop Drawings:
      1. Manufacturer’s arrangement and outline dimensions for each device.
      2. Rail Voltage Monitoring and Grounding System wiring, schematic, and connection diagrams.
      3. Enclosure details.
   C. Test and Evaluation Reports: Submit test procedures and test reports in accordance with Section 34 21 16.11, Traction Power Substation Testing.
D. Manufacturer's Instructions: Description of measures used to prevent burning of contactor.

E. Operation and Maintenance Data:
   1. Submittal information identified above.
   2. Manufacturer's operating and maintenance instructions, parts list, illustrations and diagram for components.
   3. Wiring diagram.
   4. Recommended list of spare parts.

1.04 SOFTWARE INTELLECTUAL PROPERTY RIGHTS

A. All software developed under this Contract, including source code, shall become the property of Sound Transit.

B. PLC/HMI application software development environment for all phases of the application including program development, documentation and machine startup shall be the property of Sound Transit.

PART 2 - PRODUCTS

2.01 GENERAL

A. Rail Voltage Monitoring and Grounding System shall be a separate and dedicated device which is also referred as 64V device in Section 34 21 16.23, TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices. Failure of LCMS shall not affect the functionality of the device.

B. Rail Voltage Monitoring and Grounding System shall have communication function.

   1. Rail-to-ground voltage shall be displayed on LCMS HMI (see Section 34 21 16.23, TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices) and at LCC in real time.

   2. The sampling rate of the voltage/current measurement shall be adjustable from 20 samples/second to 1 sample/second.

C. Rail-to-ground voltage/current historical data shall be stored in device itself, LCMS, and LCC for at least 7 Days. An out-of-service situation on communication network or LCC equipment shall not cause loss of historical data.

D. Provide Metal Oxide Varistor (MOV) in parallel with the shorting devices. The MOV permanently connects the negative and ground together. Provide enclosure to separate the MOV from other parts.

E. Setpoints and configuration settings shall reside in non-volatile memory in the PLC.

   1. Must be maintained before and after a power cycle or shutdown.

   2. A power cycle shall not cause setpoints, time/date, or other settings to reset to an ambiguous, unknown or default state.

   3. The latest operational setpoints and configuration settings shall be retained on the memory in the event of a PLC/HMI power cycle.
2.02 HARDWARE REQUIREMENTS

A. Rail grounding: Provide high capacity thyristors and heavy duty DC contactor as the components.

1. Thyristors:
   a. Continuous DC current rating: 500 A minimum.
   c. Continuous DC voltage rating: 550 V minimum.
   d. Peak DC withstand voltage rating: 2000 V minimum.
   e. Provide one thyristor per direction.

2. Contactor:
   a. Continuous DC current rating: 150 A minimum.
   b. Peak DC current rating: 1000 A minimum.
   c. Continuous DC voltage rating: 550 V minimum.
   d. Peak DC withstand voltage rating: 2000 V minimum.
   e. Provide a position indicator for contactor.

B. Parallel MOV:

1. Continuous operating voltage: 125 Vdc maximum.

2. Peak discharge current capacity: 40,000 A minimum.

C. Hardware:

1. LCD touch screen with voltage, current displays and history of events.
2. Resettable settings via HMI password.
3. Voltage and currents in real time both digital and chart waveform.

D. Enclosure

1. NEMA 1 metal enclosure for mounting all hardware and displays.

2.03 MONITORING AND GROUNDING FUNCTIONALITY REQUIREMENTS

A. Rail-to-ground High Voltage Protection: Activates rail grounding device and provides at least three setting stages.

1. First Stage:
   a. Voltage Setting Range: 0 to 100 V, positive or negative, in 1 V increments.
   b. Time Delay Setting Range: 0 to 20 seconds in 0.1-second increments.
   c. Default Setting: Plus or minus 90 V and 20 second delay.
2. Second Stage:
   a. Voltage Setting Range: 0 to 190 V, positive or negative, in 1 V increments.
   b. Time Delay Setting Range: 0 to 10 seconds in 0.1-second increments.
   c. Default Setting: Plus or minus 150 V and 0.5 second delay.

3. Third Stage:
   a. Voltage Setting Range: 0 to 340 V, positive or negative, in 1 V increments.
   b. Time Delay Setting Range: 0 to 5 seconds in 0.1-second increments.
   c. Default Setting: Plus or minus 340 V and 0 second delay.

B. Rail Grounding Device:
   1. Activated by rail-to-ground high voltage protection.
   2. Time duration of closure shall be adjustable.
      a. Setting Range: 1 second to 10 seconds in 0.1-second increments.
      b. Default Setting: 2 seconds.

   3. Operation:
      a. Thyristors shall always be fired and become conductive before contactor is closed.
      b. Contactor shall always be opened before thyristors are extinguished and become nonconductive.
      c. Design to prevent burning of contactor.

C. Current Monitoring Function: Monitors current through rail grounding device after rail grounding device closes, and provides overcurrent protection with two setting stages.
   1. First Stage:
      a. Current Setting Range: 0 to 100 A, positive or negative, in 1 A increments.
      b. Time Delay Setting Range: 0 to 100 seconds in 0.1-second increments.
      c. Default Setting: Plus or minus 15 A and 50-second delay.

   2. Second Stage:
      a. Current Setting Range: 0 to 1000 A, positive or negative, in 1 A increments.
      b. Time Delay Setting Range: 0 to 10 seconds in 0.1-second increments.
      c. Default Setting: Plus or minus 100 A and 1-second delay.

   3. If the current value is lower than the first stage setting, grounding device shall open after the rail grounding device time duration of closure elapses.
4. Provide the following three customer-selectable options for operation if an overcurrent protection setting is reached:
   a. Trip and reclose DC breakers (default for second stage overcurrent protection).
   b. Trip and lockout DC breakers (default for first stage overcurrent protection).
   c. Trip and lockout DC breakers and transfer trip adjacent substations.

5. Provide DC breaker trip and lockout function for repeated second-stage current values within a customer adjustable time window:
   a. Setting Range: 2 seconds to 60 seconds in 1-second increments.
   b. Default Setting: 60 seconds.
   c. Repeated second-stage current values occur if timer is picked up and dropped off more than once within the customer-adjustable time window.

D. Provide fail safe features to cover at least the following two scenarios:
   1. Breakdown of control component shall cause grounding device to close until control component is restored.
   2. Alarm signal shall be sent to LCMS and LCC if thyristor or control component fails.

E. History: Triggering alarms, failure alarms, and tripping events shall be logged into rail voltage monitoring and grounding system display panel, LCMS and LCC with time stamp. Alarm/tripping event acknowledgement shall also be logged into LCMS and LCC with time stamp.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. Field Tests and Inspections: Test Rail Voltage Monitoring and Grounding System in accordance with Section 34 21 16.11, Traction Power Substation Testing.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes.
   1. Work included is for metal-clad, medium-voltage AC circuit breaker switchgear for medium-voltage distribution system and traction power substation primary protection.

1.02 ABBREVIATIONS AND ACRONYMS

A. LCC Link Control Center
B. MVSS Medium Voltage Substation
C. NC Normally closed
D. NO Normally open

1.03 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE)
   1. IEEE C37.06 Standard for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis - Preferred Ratings and Related Required Capabilities for Voltages Above 1000 V
   2. IEEE C37.09 Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis
   3. IEEE C37.12 Guide for Specifications of High-Voltage Circuit Breakers (over 1000 Volts)
   4. IEEE C37.20.2 Standard for Metal-Clad Switchgear
   5. IEEE C37.46 Standard Specifications for High-Voltage (>1000 V) Expulsion and Current-Limiting Power Class Fuses and Fuse Disconnecting Switches
   7. IEEE C57.13 Standard Requirements for Instrument Transformers

B. National Electrical Contractors Association (NECA)
   1. NECA 1 Standard for Good Workmanship in Electrical Construction
   2. NECA 430 Standard for Installing Medium-Voltage Metal-Clad Switchgear
1.04 SUBMITTALS
A. Manufacturer’s descriptions, catalog data and other pertinent information concerning design and application ratings, service performance and reliability and information, necessary for the operation and maintenance of equipment.
B. Manufacturer’s detail drawings for each type of switchgear assembly.
C. Manufacturer’s schematic wiring and interconnection diagrams.
D. Relays, control switches, indicating lamps, protective devices and cubicle heaters. Complete description of protection devices, coordination curves, and setting procedures.
E. AC Switchgear: Complete details of circuit breakers and draw-out mechanism.
F. Ground and test device details including terminals, ports, insulation, barriers, grounding, and octopus.
G. Testing.
   1. Test procedures for each test to be performed.
   2. Test results for each test a maximum of 10 Days after date test was performed.

1.05 MAINTENANCE MATERIAL SUBMITTALS
A. Spare Parts: Provide one spare breaker of each voltage class.
B. Serial and model number information: Provide serial numbers and model numbers for all circuit breakers CTs and PTs, etc.
C. Tools.
   1. Provide one manual circuit-breaker racking handle at each switchgear location.
   2. Provide one manual crank at each switchgear location for charging circuit breaker operating mechanism.
   3. Provide 27kV and 15 kV ground and test devices in quantities as noted on the drawings. Provide one ground “octopus” for each.
   4. Provide one transfer table at each MVSS and TPSS.

1.06 QUALITY ASSURANCE / QUALITY CONTROL
A. The AC metal clad switchgear shall be UL labeled or certified as conforming to the requirements of UL and IEEE by a third party testing laboratory recognized by the State of Washington.
B. Switchgear supplier shall have and document a minimum of 10 years experience providing comparable switchgear and protective relays to industrial, transit or utility customers.
C. Testing.
   1. Factory Tests: Shall be conducted by or under the supervision of the equipment manufacturer.
   2. Field Tests: Shall be conducted by a NETA certified technician working for an independent testing company under the supervision of the Contractor. The NETA technician shall have a minimum 5 years experience testing AC switchgear and...
AC relays. The testing company shall be a NETA member. Qualifications shall be submitted for approval by the Resident Engineer.

1.07 DELIVERY, STORAGE, AND HANDLING
A. Deliver, store, protect, and handle equipment specified in this Section in accordance with manufacturer’s recommendations and NECA 430.
B. Storage of the equipment shall be arranged to prevent condensation on or in all cubicles.

PART 2 - PRODUCTS

2.01 GENERAL
A. AC switchgear shall form a line-up of dead-front, totally enclosed, free-standing switchgear suitable for indoor service.
B. Switchgear shall be metal-clad and conform to the requirements of IEEE C37.20.2, except as otherwise indicated.
C. Switchgear shall be manufactured in accordance with the referenced IEEE standards.

2.02 RATINGS
A. AC switchgear shall have the following ratings:
1. Nominal Voltage: 26.4 or 12.5 kV.
2. Maximum Voltage: 27 kV rms or 15 kV rms.
3. Frequency: 60 Hz.
4. Insulation Level, 60 Hz Withstand: 60 kV.
5. Insulation Level, Impulse Withstand: 95kV or 125 kV.
6. Continuous Current: 1200 A.
8. Maximum Dimensions: 36 inches wide, 96 inches deep, 95 inches high or as noted on drawings.

2.03 AC SWITCHGEAR STRUCTURE
A. Construction.
1. Rigid, self-supporting and self-contained.
2. Structural elements electrically welded or bolted together.
3. No. 11 gauge minimum steel.
4. Shall support equipment under normal loads, short-circuit conditions, and specified seismic conditions.
5. AC switchgear enclosure shall be divided, barriered, and partitioned into separate vertical sections.
6. Paint switchgear enclosures in accordance with Section 34 21 27, Metal Fabrication and Finishes.

B. Mimic Bus.
   1. Provide mimic bus across the entire front-face of the switchgear.
   2. Mimic bus shall be factory-applied, plastic, 3/8-inch wide and a minimum of 1/32-inch thick. Adhesive tape mimic bus is not acceptable.
   3. Indicate with symbols all circuit breakers, switches, potential transformers and incoming and outgoing feeders.

C. Circuit Breaker Compartments.
   1. Suitable for accommodation of draw-out circuit breakers.
   2. Provide supporting rails for the circuit breakers that allow the circuit breakers to be easily drawn in or out of their housing.
      a. Circuit breakers shall draw out from the lower compartment directly onto the floor. Circuit breakers in upper compartments are not allowed.
      b. Provide guide rails or cradles for positioning the removable elements as an integral part of the equipment. Guides shall ensure proper alignment.
   3. Provide self-aligning, self-coupling, primary and secondary disconnecting devices that allow the draw out breakers to connect or disconnect from the buses and auxiliary circuits.
      a. Provide automatic protective shutters to cover live high-voltage terminals and prevent accidental contact with live parts as the removable element of breaker is drawn out of the cubicle.
      b. Connection of control wiring to the AC breaker shall be by sliding contacts. A plug-style disconnect is acceptable, provided the breaker cannot be mechanically racked into the connected position with the plug disconnected.
   4. Provide a manual racking mechanism for horizontal draw-out of each circuit breaker:
      a. Mechanism shall have three circuit breaker positions: Disconnected, test, and connected.
      b. Provide positive stops to prevent over-travel at each position.
      c. Mechanism shall be designed for racking of circuit breaker in and out of connected and disconnected position with the compartment front door in the closed and latched position.
      d. When the breaker is in the connected and test positions, the case and frame shall be grounded by means of a positive contact with a copper ground bus.
   5. Provide remote-racking system including linkages, motor mechanism, and control station with umbilical cord. Racking shall be possible by a worker located at least
ten feet to either side of the affected circuit breaker compartment. Provide one remote-racking system for each MVSS or TPSS.

6. Provide the following interlocks:
   a. Prevent either electrical or manual operation of the breaker unless it is in the Connected or Test position.
   b. A positive mechanical interlock shall prevent racking in or out unless the breaker is in the Open position.
   c. Circuit breaker, complete with the operating mechanism shall be capable of being removed from the enclosure only in the Disconnected position.

D. Control/Terminal Board Compartment.
1. Controls, including programmable controllers, instrumentation, control relays, terminal boards, control wiring and control devices shall be housed in a separate control/terminal board compartment.
2. Compartment shall be barriered from the power wiring and bus work compartments.
   a. Exception. Where controls and terminal boards are dedicated to circuit breaker function, they may be located in the circuit breaker compartment.
3. Protective relays, meters, instruments and control devices shall be mounted on front compartment doors.

E. Access Doors.
1. Access to all components shall be from the front and the rear. When doors are opened to 120-degree stop position, it shall be possible to open adjacent cubicle doors.
2. Equipment access panels located on the side or top of the enclosures are prohibited.
3. Provide each compartment with separate hinged front and rear access doors for servicing.
4. Opening of any front door shall not expose circuits in adjacent compartments.
5. Construction.
   a. No. 11 gauge minimum sheet metal.
   b. Properly reinforce against distortions using suitable flanges and stiffening members.
7. Latches.
   a. Doors shall be securely fastened in the closed position with a three-point latch easily opened without the use of tools.
   b. Two latches will be allowed if front panel consists of more than one full-length door.
8. Handles: Provide each door with a heavy duty-handle.

9. Door Stops: Provide each door with a heavy-duty stop to hold it securely in the open position.

F. Heaters.

1. Provide heating strips in each cubicle. Operating voltage for heating strips shall not exceed 50 percent of heater rated voltage.

2. Provide an individual thermostat to control heater in each cubicle. Locate in a general area such that cool air in the lower portion of the cubicle can be sensed by the thermostat.

G. Lights: Provide linear LED lighting strips, mounted vertically in the left and right front corners of the control/terminal board compartment of each cubicle and directed at the control/terminal panel. Lighting strips to be 18 inches minimum in length and provide accurate rendering of wire colors.

H. Warning Signs.

1. Front Access Doors: Sign on each stating "DANGER: LIVE PARTS" and "DANGER: HIGH VOLTAGE."

2. Rear Access Doors.
   a. Sign on each stating "DANGER: LIVE PARTS" and "DANGER: HIGH VOLTAGE."
   b. Sign on each removable Glastic panel inside access door stating, "DANGER: HIGH VOLTAGE."

2.04 MEDIUM-VOLTAGE CIRCUIT BREAKER

A. General.

1. Circuit breaker shall be a draw-out type and utilize vacuum interrupters having load and fault break capabilities and shall conform to or exceed the requirements of IEEE C37.06 and IEEE C37.12.

2. Circuit breakers shall be identical and physically and electrically interchangeable.

3. Circuit breaker frame shall be provided with a full front metal shield to prevent access to any live primary bus or load terminals when the circuit breaker is in the connected position.

4. Provide a truck or fifth wheel at each switchgear location to facilitate one-person breaker removal and turning.

5. Provide means for padlocking the AC breaker in the open position.

   a. Noncombustible, non-hygroscopic and track-resistant.
   b. Mechanical strength and physical characteristics shall match the stresses imposed by the circuit breaker rated momentary current.

B. Minimum Ratings.
1. **Nominal System Voltage:** 26.4Y/15.2 kV or 12.5Y/7.2 kV three-phase, solidly grounded.
2. **Maximum Voltage:** 27 kV rms or 15 kV rms.
3. **Frequency:** 60 Hz.
4. **Insulation Level, 60 Hz:** 36 kV, rms.
5. **Insulation Level, Impulse:** 125 kV, crest.
6. **Short Circuit Current at Maximum Voltage:** 25 kA rms.
7. **Continuous Current:** 1200 A.
8. **Closing and Latching Capability:** 62 kA rms.
9. **Fault Clearing Time:** 5 cycles max.

**C. Circuit Breaker Operating Mechanism.**

1. Motor-charged and spring-operated unless otherwise approved by Resident Engineer.
2. Mechanism shall be designed to prevent overcharging.
3. The mechanism shall ensure that the release of stored energy for closing the circuit breaker main contacts is prevented unless the mechanism has been fully charged.
4. The stored-energy closing mechanism shall automatically charge itself within 15 seconds after closing of the breaker.
5. Energy storage shall be sufficient for an open-close-open cycle at maximum rated short circuit current.
6. A manual cranking feature shall be included on the operating mechanism to permit spring charging in the event motor power is unavailable. Provide an interlock to prevent withdrawal of the circuit breaker from the enclosure when the mechanism is in the fully charged state.
   a. Automatic controlled discharge of the stored energy when the circuit breaker is withdrawn from or inserted into the enclosure will also be acceptable.
7. Circuit breaker shall be electrically and mechanically trip free. The operating mechanism shall be non-pumping.
8. Provide a four-digit, non-resettable, register-type mechanical operations counter on each circuit breaker to record each close/open cycle.

**D. Circuit Breaker Control.**

1. **Control Voltage:** 125 Vdc.
2. **Closing Mechanism:** Provide with a spring release coil, anti-pump relay and spring charging motor suitable for operation over a voltage range from 85 percent to 115 percent of the nominal dc control voltage.
3. **Tripping Mechanism:** Provide with a shunt trip coil suitable for operation over a voltage range from 75 percent to 125 percent of the nominal dc control voltage.
4. Control Switches.
   a. Open/Close: Switchboard type heavy-duty pistol-grip control. Control switch shall permit open and close operations when the circuit breaker is in the connected or test position.
   b. Provide a switch for resetting the circuit breaker after a trip and provide a mechanical trip indication at the control switch.
   c. Local/Remote (Device 43): Switch mounted on the front of the cubicle. Provide positive stops in both positions.

5. Auxiliary Contacts: Provide a minimum of six electrically separate sets of reversible auxiliary contacts, in addition to those required for the circuit breaker control circuit.
   a. Auxiliary contacts shall be operated by the breaker mechanism in both the Connected and Test positions.
   b. Spare auxiliary contacts shall be wired to the outgoing terminal blocks.

E. Trip Circuit Monitor.
   1. Provide a trip circuit monitor for monitoring the trip coil on each AC circuit breaker and lockout relay.
   2. Monitor shall have NO and NC Form C contacts for indication of a failed trip coil.
   3. Monitor shall have a 200 millisecond delay to allow for auxiliary contacts to transfer.
   5. Trip coil status shall be monitored by SCADA.
   6. Manufacturer: E-max RAW-1D or approved equal.

F. Indicating Lights.
   1. Provide indicating lights on the front of the circuit breaker enclosure to indicate the state of the circuit breaker:
      b. Tripped or Open Breaker: Green light.
   2. Provide an amber LED above each local/remote switch that illuminates to indicate switch is in local position.
   3. Provide a white LED indicating light on the front of the circuit breaker enclosure to indicate the stored-energy closing mechanism is charged.
   4. Trip Circuit Monitor.
      a. Provide a green LED that illuminates when the trip coil is energized and turns off when the coil is de-energized.
      b. Provide a red LED that illuminates upon failure of the trip coil.
   5. LEDs:
a. Plug-in replaceable with a life of 100,000 hours.

b. Protected against reverse polarity by a diode.

G. Lock Out Relay (Device 86): When the main AC circuit breaker is tripped by the lockout relay, the following sequence of events shall occur:

1. DC positive main circuit breaker shall be opened for traction power substations.

2. AC breaker shall be locked out until manually reset.

2.05 BUSES AND CONNECTIONS

A. Main horizontal three-phase bus shall be fabricated from silver-plated, electrical grade copper and extend the full length of the switchgear.

B. Bus, including joints, shall be insulated the full length with flame-retardant, non-hygroscopic, track-resistant insulation over its entire length rated 30 kV. The method of bus insulation and the insulating material shall conform to ANSI C37.20.

C. All connections, including bus taps, circuit breaker connections, connections to CTs and PTs and transformers, shall be bussed using the same material as the main horizontal bus with silver plated copper and joined with a minimum of two bolts and Belleville washers per joint. After final torqueing all bolted connections shall be torque striped. Cable connections are not permitted.

D. Hardware shall be silicon bronze.

E. Continuous current rating of all main bus and circuit breaker connections shall be at least 1200 A.

F. Buses and bus connections shall be adequate to withstand thermal and mechanical stresses associated with short-circuit currents equal to the momentary and 2-second rating of the circuit breaker.

G. A copper ground bus, not less than 2 inch by 1/4 inch, shall extend the length of the AC switchgear assembly and be bonded to each switchgear section by solidly bolting the bus to a non-removable structural member. After final torqueing all bolted connections shall be torque striped.

2.06 UTILITY INCOMING SECTION

A. Provide supplementary equipment as required to connect switchgear relays and power meter to Sound Transit SCADA system.

B. Provide utility metering sections as noted on Contract Drawings for substations meeting EUSERC requirements and complying with Utility standards.

2.07 PROTECTIVE RELAYS

A. Protective relays shall be of the microprocessor-based IED(Intelligent Electronic Devices) type capable of interconnecting with programmable control (PLC) supervisory devices and shall be flush mounted, with wiring connections on the back of the relay.

B. Protective relays shall be provided with integral test switches.

C. Protective relays shall have rustproof metal or high-impact plastic rectangular cases.
D. Contacts shall be silver-plated and non-welding. Provide relays conforming to the applicable sections of IEEE C37.90.

E. Devices including switches, relays, indicating lights and test plugs shall be arranged to be conveniently accessible and easily visible. The grouping shall be modular and place related functions in proximity.

F. Devices shall be mounted plumb and square with the lines of the panels and as recommended by the manufacturer. Relays or devices shall be mounted on hinged or removable panels and shall not be mounted on a fixed portion of the switchgear.

G. Design metering compartment to avoid wiring congestion. Auxiliary devices shall match the general appearance as far as possible with frames of a compatible color.

H. Devices of the same general type shall be manufactured by the same company and shall be similarly arranged and mounted.

I. At a minimum, the following protective and monitoring devices shall be provided as shown on the one-line drawings in the Contract Documents. Additional protective devices recommended by Contractor or equipment manufacturers may be installed with Resident Engineer approval.

1. Phase Fault Overcurrent Relays.
   a. The primary function of the phase overcurrent relays (Device 50/51) shall be to provide overload and fault protection for loads served.
   b. Relays shall be designed to compile a composite time overcurrent characteristic curve which shall best match the normal and overload requirements of the load and to match the thermal and mechanical withstand of transformers.
   c. Each relay, (Device 50/51) shall provide for both instantaneous and time delay overcurrent protection.

2. Ground Fault Overcurrent Relay.
   a. A residual instantaneous and time delay relay (Device 50N/51N) shall be provided and connected in such a way as to provide sensitive ground fault detection.
   b. This relay shall be field adjustable.

3. Loss of Phase/Phase Sequence.
   a. The three-phase voltage protective relay (Device 47) shall be provided and connected in such a way as to provide open-phase protection.
   b. This relay shall contain a field adjustable time delay.

4. Undervoltage.
   a. The primary function of the undervoltage relay (Device 27) shall be to trip and annunciate an AC input voltage of less than 80 percent of the nominal voltage.
   b. This relay shall also trip and annunciate a loss of voltage due to utility outage.
c. This relay shall be provided with a 0.5 to 4 second adjustable time delay before tripping.

5. Reverse Power.
   a. Provide reverse power (Device 32) protective relaying function in incoming feeder cubicles connecting to utility service switchgear. This device shall trip and lock-out associated circuit breaker when it detects a flow of power from Sound Transit back toward the utility.

   a. Lockout relay (Device 86) shall be provided on the AC circuit breaker compartment. A pistol-grip switch shall be provided for resetting of the lockout relay.
   b. Provide indication of "lockout" and "normal" at the reset switch.

2.08 INSTRUMENTS AND METERS
   A. The accuracy of all indicating instruments shall be within 1 percent of full scale reading.
   B. Voltmeters and ammeters shall be suitably rated for use with the corresponding transformer.
   C. Scales shall be of a suitable range, equal to the associated potential or current transformer primary rating.
   D. Provide incoming-line phase-selector switches for connection to the line transformers for the ammeter and voltmeter.
   E. Provide power meter in accordance with Section 26 09 16 Electrical Power Monitoring.

2.09 INSTRUMENT TRANSFORMERS
   A. Instrument transformers shall conform to IEEE C57.13, with the additional requirements indicated below.
   B. Current Transformers.
      1. Shall be capable of withstanding thermal and mechanical ratings of the circuit breaker.
      2. Molded-rubber or epoxy construction, wound-type or bushing-mounted.
      3. Wound-Type Current Transformers.
         a. Provide separate compartment isolated from the control panel and all other equipment.
         b. Provide a mounting frame which bolts securely to the switchgear frame.
         c. Transformers shall have full-wave impulse insulation level of 125 kV.
         d. Secondary terminal blocks shall have covers with integral shorting bars and secondary wiring shall be run to readily identifiable terminal block points in the control compartment.
         e. Terminal block points shall also have integral shorting bars for the current transformer leads.
4. Bushing-Type Current Transformers.
   a. Low-voltage, ring-core, high-accuracy type designed for secure mounting on the primary contact support bushings.

5. Accuracy.
   a. Protective Relaying: Current transformers shall satisfy the requirements for relaying accuracy classification, under the burdens imposed by the devices specified herein.
   b. Power Meters.
      1) Current transformers shall be metering class 0.15 at burden B0.2.
      2) If this metering accuracy is not available, perform an analysis of expected accuracy of metering equipment for loads from 1 percent to 100 percent of actual load rating and submit for approval.
      3) Bushing current transformers that will not provide accuracy of plus or minus 0.3 percent at 10 percent load and plus or minus 0.5 percent at full load will be rejected and require installation of wound-type current transformers.

C. Potential Transformers.
   1. Drawout-type, molded-rubber or epoxy construction.
   2. Transformers shall have full-wave impulse insulation level of 150 kV.
   3. Primary and secondary circuits of all potential transformers shall be fused by means of non-renewable cartridge-type fuses meeting requirements of IEEE C37.46.
   4. Grounding: The potential transformer shall be visibly grounded when the primary circuit is disconnected and in position for inspection.
   5. Fuses.
      a. All primary fuses shall be completely disconnected before access can be obtained to either the transformer or its high-voltage fuses.
      b. Secondary circuit fuses shall be installed in the low-voltage circuits and shall be located to permit replacement when the switchgear is in operation.
   6. Rating: All potential transformers shall be adequately rated in accordance with the burden requirements of the accuracy classification and capable of carrying rated load continuously without excessive heating or damage.
   7. Accuracy: Potential transformers for power meters shall have accuracy class 0.3 at W, X, M, and Y burden.

2.10 SCADA
A. Devices furnished under this Contract shall be provided with additional terminations within their respective control enclosures for connection to the TPSS Local Centralized Monitoring System which includes interface with the Sound Transit supervisory control system. Refer to Contract Drawings for typical SCADA points for each type of circuit breaker.
2.11 GROUND AND TEST DEVICE

A. Ground and test device shall be readily adaptable to line or load terminals, which can be connected onto individual phases with ground connector for external connection to station ground. Provide standard “ball” type connectors for positive connection to studs on ground and test device terminals.

B. Device shall be capable of being racked into cubicle with circuit breaker racking handle.

C. Line and load terminals and phases shall be separated by barriers.

D. Provide ports on front of ground and test devices for insertion of standard “Biddle” high voltage tester and grounding “octopus”.

E. Provide visual means of viewing line and load terminals.

F. Device shall be continuously grounded as it is inserted into cubicle.

G. Ground Octopus.
   1. Three-phase.
   2. Connectors: Three ball/socket-type, compatible with grounding studs on ground and test device and one C-clamp type for connection to ground bus.
   3. Readily connected with a hot stick.
   4. Length: Sufficient to allow connection to the closest ground bus when ground and test device is fully inserted into each AC breaker cubicle.

2.12 TRANSFER TABLE

A. Provide transfer tables for removing and lowering PTs and draw-out fuse trunions.

B. Table shall be capable of being raised and lowered hydraulically from floor to trunion levels.

2.13 SOURCE QUALITY CONTROL

A. Factory Design Tests.
   1. Tests shall consist of all design tests as specified in IEEE C37.20.2.
   2. Perform tests on the AC switchgear assembly and each component of the AC switchgear.
   3. The main AC circuit breaker test shall be performed in accordance with the design tests as described in IEEE C37.09.

B. Factory Production Tests.
   1. Perform on AC switchgear in accordance with IEEE C37.20.2:
      a. Dielectric tests.
      b. Mechanical operation tests.
      c. Electrical operation and control wiring tests, except that the control wiring continuity shall be verified by actual electrical operation of control devices.
      d. Grounding of instrument transformer cases.
2. Perform on each AC circuit breaker in accordance with IEEE C37.09 prior to mounting inside AC switchgear:
   a. Nameplate check.
   b. Control and secondary wiring checks.
   c. Clearance and mechanical adjustment check tests.
   d. Mechanical operation tests.
   e. Timing tests.
   f. Stored energy system tests.
   g. Conductivity of the current path test.
   h. Low-frequency withstand voltage tests on major insulation components.
   i. Current transformer.
   j. Resistors and coils.

   a. Check for accuracy, performance and operation in accordance with IEEE C57.13.

PART 3 - EXECUTION

3.01 INSTALLATION
   A. Switchgear shall be installed in accordance with manufacturer's installation instructions, NECA 1, and NECA 430.

3.02 PROTECTIVE DEVICE COORDINATION
   A. Perform a Coordination Study for the AC system to ensure that the protective devices will function together, in conformance with Section 34 21 73, TE System Studies.

3.03 SURGE ARRESTER GROUNDING
   A. The surge arrester ground terminals shall be connected directly to the switchgear ground bus connected to the station grounding electrode. Surge arresters in Service Switchgear are furnished by Utility.

3.04 FIELD QUALITY CONTROL
   A. AC Switchgear.
      1. The following tests shall be performed after installation of the AC switchgear:
         a. Continuity and insulation resistance tests phase-to-ground and phase-to-phase, for all buses with a 2500 Vdc megohmmeter for one minute.
         b. High potential test to ground and between phases on medium-voltage buses with circuit breakers racked-in and closed.
         c. Verification of proper operation of each interlock and protective device.
d. Test of each AC protection relay using a three-phase current/voltage injection test device. Test device shall have the following functions:

1) Current/voltage magnitude.
2) Frequency and angle are adjustable per phase.
3) Internal digital timer is programmable to start and stop.

e. Each recommended AC relay protection setting shall be verified and tested.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. DC switchgear and section tie breakers.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. Institute of Electrical and Electronics Engineers (IEEE):
   b. IEEE C37.16 - Standard for Preferred Ratings, Related Requirements, and Application Recommendations for Low-Voltage AC (635 V and below) and DC (3200 V and below) Power Circuit Breakers.
   c. IEEE C37.20.1 - Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear.

2. Underwriters Laboratory(UL)
   a. UL 1449 – Standard for Surge Protective Devices

1.03 SUBMITTALS

A. Product Data: Complete manufacturer’s product descriptions and catalog data, including information on the following:

1. Design and application ratings.

2. Service performance, reliability and proven service history record.

3. Relays, controls, switches, indicators, load measuring devices, resistors and cubicle heaters.

4. Key Operated Mechanical Interlock: Catalog data.

B. Shop Drawings:

1. Manufacturer’s Drawings:
   a. Arrangement drawings.
   b. Schematic wiring diagrams.
c. Interconnection diagrams.

d. Mechanical plans of circuit breakers and cubicles and cross sections thereof.

2. Complete details of transfer trip scheme and remote trip scheme for the DC breakers and their interfaces with the fiber optic links.

3. Mechanical interlocking scheme, including description, and detailed arrangement drawings.

C. Test and Evaluation Reports: Submit test procedures and test reports in accordance with Section 34 21 16.11, Traction Power Substation Testing.

D. Operation and Maintenance Data:

1. Submittal information identified above.

2. Manufacturer’s operating and maintenance instructions, parts list, illustrations and diagram for components.

3. Wiring diagram.

4. Recommended list of spare parts

1.04 QUALITY ASSURANCE

A. DC Switchgear: UL labeled or furnished with a Field Evaluation labels in accordance with Section 34 21 10, Traction Electrification System General Requirements.

PART 2 - PRODUCTS

2.01 GENERAL

A. DC Switchgear: Dead-front, self-ventilated, metal enclosed, free standing, sheet steel enclosures suitable for indoor service.

B. Provide access to removable components of the switchgear from the front.

C. Locate bus and power wiring in the rear.

D. Provide switchgear with individually enclosed, draw-out type, high speed, power circuit breakers rated for use with the transformer-rectifier unit.

E. Include DC buses and connections, positive or negative feeder cable terminal connections, indicating lights, terminal blocks, protective and auxiliary relays, control circuitry, wiring and all other devices necessary to make a complete and operable switchgear assembly.

F. Design, materials, construction, and tests shall be in accordance with IEEE C37.14 and C37.20.1 and as further described or modified in this Section.

2.02 RATINGS

A. The switchgear assembly and circuit breaker shall have the following minimum ratings in accordance with IEEE C37.14 and IEEE C37.16:
<table>
<thead>
<tr>
<th></th>
<th>Feeder</th>
<th>Main</th>
</tr>
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<tbody>
<tr>
<td>Full-Load Voltage</td>
<td>1500 Vdc</td>
<td>1500 Vdc</td>
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<td>Maximum Voltage</td>
<td>1900 Vdc</td>
<td>1900 Vdc</td>
</tr>
<tr>
<td>Continuous Current</td>
<td>4000 A</td>
<td>6000 A</td>
</tr>
<tr>
<td>Minimum frame size</td>
<td>4000 A</td>
<td>6000 A</td>
</tr>
<tr>
<td><strong>Insulation Level:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 Hz withstand</td>
<td>5.6 kV, rms</td>
<td>5.6 kV, rms</td>
</tr>
<tr>
<td><strong>Short circuit rating:</strong></td>
<td>100 kA, peak</td>
<td>100 kA, peak</td>
</tr>
</tbody>
</table>

2.03 SWITCHGEAR ENCLOSURE

A. Switchgear Structure:

1. Steel, rigid, self-supporting, self-contained, conforming to IEEE C37.20.1 and to requirements indicated below.

2. Fabricated of electrically welded or bolted No. 11 gauge minimum steel.

3. Provide enclosures sufficiently rigid to support equipment under normal loads, short-circuit conditions, and specified seismic conditions.

4. Apply powder coat finish to switchgear assembly in accordance with Section 34 21 27, Metal Fabrication and Finishes.

B. Doors:

1. Material: No. 11 gauge minimum sheet steel properly reinforced against distortion by suitable flanges and stiffening members.


3. Handle: Heavy duty, easily operated, one for each door.

4. Latches: Minimum of three latches shall securely fasten door in the closed position and shall be easily opened without the use of tools. Two latches will be allowed if the front panel consists of more than one full-length door.

5. Door Stops: Heavy duty to hold door securely in the open position. Not easily bent if an attempt is made to close door without releasing door stop. Provide opening door swing of 120 degrees.

6. Doors shall be electrically connected to the enclosures with bonding jumpers.

C. Lighting: Provide lighting and switching in each cubicle complying with Section 34 21 16.17 Prefabricated traction Power Substation Building for Substation Lighting.

D. Heating: Provide two thermostatically-controlled strip-type heaters in each cubicle to prevent condensation.

1. Operating voltage for heating strips shall not exceed 50 percent of heater rated voltage.
2. Provide an individual thermostat for each cubicle.

3. Locate thermostat in a general area of each cubicle so that cool air at the lower portion of the enclosure can be sensed by the thermostat.

4. Power heaters from 120 Vac auxiliary power system using an isolation transformer, as specified in Section 34 21 16.21, TPSS – Control Power.

E. Warning Signs:

1. Provide "DANGER: LIVE PARTS" and "DANGER: HIGH VOLTAGE" signs on front, rear, and side access doors of cubicles where 1500 Vdc wiring is present.

2. Provide “DANGER: HIGH VOLTAGE” signs on removable Glastic panels inside rear access doors.

F. DC Circuit Breaker Cubicle:

1. Suitable for accommodation of drawout circuit breakers.

2. Provide supporting guide rails for positioning the removable elements as an integral part of the equipment.

3. Design such that circuit breakers are easily drawn in or out of their housings.

4. Include stationary disconnecting device contacts for the circuit breakers.

5. Breakers shall connect or disconnect from buses and auxiliary circuits by means of self-aligning, self-coupling, primary and secondary disconnecting devices.

6. Provide self-alignment mechanisms such that misalignment of contact is not possible when circuit breaker elements make contact with stationary contacts.

7. Connection of control wiring to the DC breaker may be by movable contacts or by a plug-style disconnect.

   a. Plug style disconnect:

      1) It shall not be mechanically possible to rack breaker into the connected position with the plug disconnected.

      2) Locate where easily accessible. Resident Engineer will make final determination whether location is easily accessible.

      3) Provide heavy-duty connection hardware not easily bent or broken due to mishandling.

8. Provide suitable shrouds or automatic safety shutters on devices to prevent accidental contact with live parts.

9. Provide each enclosure with protective shutters that cover live high-voltage terminals when the access door is opened or a DC feeder breaker is racked out of the cubicle.

10. Provide each compartment with a hinged door or full width drawout panel for front access to the circuit breakers, instruments and terminal blocks.

11. Provide rear access doors to facilitate access to the DC power bus. Doors shall swing fully open against the adjacent door or enclosures. Coordinate cubicle rear
access doors with substation enclosure access doors to provide complete access to rear of all cubicles.

12. Provide connections to the DC feeder cables in the rear compartment.

13. Construct enclosures to allow for the dissipation of ionized gas from the circuit breaker arc chutes without hazard to personnel from the discharge of hot gas or other materials.
   a. Release gas from the units to the outside of the enclosure by means of suitable stacks, louvered vent openings, or vent openings covered with grilles.
   b. Provide adequate clearance to ground to prevent the possibility of establishing a conducting path to grounded structure or objects when interrupting maximum short-circuit energy at rated maximum voltage.
   c. Line enclosure surfaces exposed to arcs or ionized gases with flame resistant, high dielectric insulating materials.
   d. This paragraph is not intended to require the use of arc-resistant switchgear.

14. Stacking of DC circuit breakers in cubicles is not permitted.

G. Negative Switch Cubicle:
   1. Provide a separate isolated compartment or cubicle with a hinged door containing a clear window in the panel for viewing the position of the negative switch.
   2. Negative switch shall be isolated from rectifier.

H. Separate high-voltage devices from low-voltage controls and make readily identifiable by color coding mounting panel.
   1. No controls are allowed in rear cable or bus compartment.
   2. Adhesive wire supports are not acceptable.
   3. All control wire in high-voltage cubicles shall be 2.4 kV rated.

I. No dedicated control compartment is required. The control devices can share the same compartment with the protection devices.
   1. Control/protection compartment shall be dead-front and shall consist of hinged swinging panels mounted on the switchgear frame.
      a. Construct swinging panel doors to support flush and semi-flush mounted devices.
      b. Swinging panel doors shall not distort from a plane surface in any position.
      c. Swinging panel doors of control/protection compartment shall be supported by stainless steel hinges.
      d. Panel doors shall swing open and provide free access to the area behind the panel, the rear of the devices mounted on the panels, wiring, terminal blocks, and auxiliary devices mounted within the compartment.
e. Secure swinging panel doors in the closed position with two positive latching or screwed fasteners that can be operated by hand without tools.

f. Swinging panel doors shall open 90 degrees and be held with heavy duty stops.

g. Open doors to allow removal of circuit breaker elements from adjacent cubicle(s).

2. Provide Surge Protective Device (SPD) for control power circuit in each Control/Protection compartment.

a. The SPD shall be UL-1449 listed, with minimum 10 kA nominal discharge current, plug-on and hot swappable type.

b. The SPD voltage level shall be rated according to field control power voltage level and shall be equipped with operational status LED.

c. The SPD shall be with thermally protected metal oxide varistor (MOV).

2.04 NEGATIVE DISCONNECT SWITCH – 89N

A. Provide a negative DC disconnect switch (Device 89N) mounted in negative switch cubicle in each substation DC switchgear assembly, as shown in the Contract Drawings.

1. Install between the negative return cable and the rectifier negative pole.

2. Rated to carry 6000 A continuous current at 1500 Vdc and withstand bolted short-circuit currents of 50,000 A.

3. Insulation level shall be sufficient to pass 1 minute 60 Hz dry withstand test at 5.7 kV, rms.

4. Manually-operated, single-pole, jaw-pressure-type, solid copper blade with silver plated contacts and an insulated operating handle.

B. Design with interlocking feature to ensure it can be opened only under no-load.

1. Key interlocked with the positive main DC circuit breaker to prevent main DC circuit breaker from closing when the negative disconnect switch is open. The interlock shall also prevent negative disconnect switch from opening when the main DC circuit breaker is closed.

2. Interlock requirements as follows:

   a. Key removal from the negative disconnect switch shall be possible only when the negative disconnect switch is closed.

   b. Opening of negative disconnect switch shall require the key to be inserted in the negative disconnect switch.

   c. With the key removed from the main DC circuit breaker it shall be mechanically locked open and the electrical closing circuitry shall be disabled.

C. Provide a green and a red indicating light on the front panel of cubicle:

2. Red Illuminated: Switch closed.

D. Provide a simple operation instruction nameplate on the cubicle door.

2.05 CIRCUIT BREAKERS

A. Main switching and interrupting device of the DC breakers shall be of the removable type arranged for moving physically between connected, test and disconnected positions.

B. DC circuit breakers and tie breakers of the same type and rating shall be identical and physically and electrically interchangeable.

C. DC Circuit Breakers: Single-pole, air-break, high-speed, removable type:
   1. Manufactured in accordance with IEEE C37.14, and rated according to the preferred ratings listed in IEEE C37.16, except as modified in this Section.
   2. Suitable for local and remote supervisory control.
   3. Electrically operated and electrically and mechanically trip-free with the mechanism ensuring full contact pressure until time of opening.
   4. Insulated to withstand 5.6 kV, rms at 60 Hz for 1 minute.
   5. Peak rated momentary current, feeder and main breakers: 100 kA, minimum.

D. Provide each main and DC feeder circuit breaker with a direct-acting, non-directional, instantaneous overcurrent tripping device (Device 76) adjustable between 200 percent and 400 percent of the breaker rating.

E. Set direct-acting, non-directional, instantaneous overcurrent tripping device (Device 76) initially at 200 percent of the DC feeder breaker rating.

F. Contacts:
   1. Surfaces of the moving and stationary contact members of the main contacts shall be silver, non-welding silver alloy, or equivalent that combines high conductivity and necessary arc-resistant properties.
   2. Main and secondary contacts of breaker shall be removable for replacement.

G. Operating Mechanism:
   1. Solenoid-operated or motor-charged stored-energy, spring-operated type.
      a. In the event the breaker does not close or the closing control circuit is not opened, a trip sequence shall be initiated to open the closing control circuit and restore all closing sequence relays to their normal position.
      b. Motor-charged and spring-operated mechanisms shall meet requirements of Section 3421 19.13, Medium-Voltage AC Circuit Breaker Switchgear.
   2. Mechanism shall be non-pumping.
   3. Design shall ensure positive opening of the moving contacts and circuit interruption when the tripping impulse is received at the fully closed or any partially open position.
4. Provide control with a shunt trip device with the necessary auxiliary control equipment.

H. Request to close any DC feeder breaker shall be governed by the load measure reclose system. Provide sufficient logic to ensure any response to a remote closure request will not result in an unsafe condition or cause damage to the substations or any of its components.

I. Make provisions for moving each breaker to a "connected", "test" and "disconnected" position with positive stops in each position.

1. In the "connected" position, both the primary disconnecting devices and the secondary disconnecting devices shall be in full contact and the breaker shall be in position for normal operation.

2. In the "test" position, the primary disconnecting devices shall be open and separated by a safe distance and the secondary disconnecting devices shall be in full contact.

3. In the "disconnected" position both the primary and secondary disconnecting devices shall be open and separated by a safe distance.

4. In the "test" and "connected" positions, provide each circuit breaker with mechanical means for manually tripping the circuit breaker. This function shall be available with the compartment door closed.

J. Interlocks:

1. Provide mechanical interlocks to prevent moving the circuit breaker in or out of the "connected" position when the circuit breaker main contacts are in the closed position.

2. Provide mechanical interlocks for each breaker compartment and circuit breaker combination to prevent closing the circuit breaker manually unless the breaker is in the "test" or "disconnected" position.

3. Provide electrical interlock to prevent closing circuit breaker electrically, unless the circuit breaker is in the fully "connected" position with the primary disconnecting devices in full contact, or in the "test" position.

K. Provide a mechanical indicator to show the location of the circuit breaker in "connected," "test," or "disconnected" positions.

L. Provide red and green indicating lights on each breaker unit for electrical closing and opening of the breaker while in the "test" or "connected" positions.

1. Red Light Illuminated: Breaker closed.

2. Green Light Illuminated: Breaker open.

3. Provide long life, high brightness and high visibility, LED array lights.

M. Breaker control switch: Heavy duty, switchboard type, pistol grip control, rated for the load.

N. Bypass Load Measuring:

1. Provide control on DC multifunction protective relay that allows an authorized operator to bypass load measure system when closing breaker.
2. Feature shall be capable of being enabled or disabled.

O. Provide a mechanical indicator, visible when the door is closed, to show when the circuit breaker is in the "open" and "closed" condition.

P. Provide additional terminations for devices that have electrical opening or closing functions, within their respective control relay enclosures, for connection to the SCADA control system. Refer to Section 34 21 16.23, TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices.

Q. Provide a local/remote switch to select local or remote control:
   1. Switch: Heavy-duty selector switch rated for the load.
   2. Provide a white LED mounted above the switch to illuminate when switch is in local position.

R. Provide a minimum of four electrically separate sets of reversible auxiliary contacts, in addition to those required for the circuit breaker control circuit.
   1. Auxiliary contacts shall be operated by the breaker mechanism in both the "connected" and "test" position.
   2. Spare auxiliary contacts shall be wired to the outgoing terminal blocks.

S. Provide four-digit, non-resettable, register-type mechanical operations counter on each circuit breaker to record tripping operations.

T. Circuit Interruption Arc Chutes:
   1. Metal plate or magnetic coil type.
   2. Suitable for bidirectional current flow.
   3. Designed for positive interruption of currents from 0 V to circuit breaker maximum rating.
   4. Provide with an air puffer device to extinguish low current arcs.

U. Provide means to permit padlocking the DC breaker in the open position to prevent inadvertent closure without having to withdraw the breaker element.

V. Provide circuit breakers with approved wheels to remove element from cubicle. Provide a fifth wheel or similar arrangement to assist in moving breaker element within substations. Wheels shall not damage epoxy floor coating.

W. Interchangeability:
   1. Removable elements of the same type and rating shall be completely physically and electrically interchangeable.
   2. Removable elements not of the same type of rating shall not be physically interchangeable.

2.06 BUS AND BUS CONNECTIONS

A. Main horizontal DC switchgear bus shall be an extension of the rectifier bus, run the length of the DC switchgear. Tap to serve each circuit breaker.
B. Bus: Electrical grade copper with high electrical conductivity.
   1. DC Main Bus: Rated 6000 A.
   2. Feeder Bus: Rated 4000 A.

C. Bolted bus connections, including bus taps, circuit breaker connections, cable connections,
   and connections of devices such as transducers and shunts, shall be silver-plated copper
   and joined with a minimum of two bolts and Belleville washers per joint.

D. Each joint shall have conductivity at least equal to that of the bus bar and each joint shall
   be so clamped that no loss of conductivity will occur during the life of the switchgear.

E. Insulate main bus and feeder bus from each other with electrical insulating laminate barrier
   or other approved means.

F. Bus and bus connections shall be of adequate strength to withstand thermal and
   mechanical stresses resulting from the maximum available short-circuit current or the rms
   interrupting rating of the circuit breakers, whichever is greater, without damage or
   permanent distortion.

G. Mount bus bars on barrier-type insulation or post-type insulators of sufficient strength and
   braced to withstand, without damage or permanent distortion, all stresses produced by the
   maximum available short-circuit currents.

H. All connections to the bus shall be bolted. All bolted connections to be properly torqued
   and accordingly marked after installation. Bolts shall be silicon bronze of sufficient number
   and size for application. All connections shall be accessible for inspection and torque
   checking without removing cubicle from switchgear lineup.

2.07 TPSS DC CABLE CONNECTIONS

A. Provide ample space for pulling and terminating the feeder cables entering or leaving the
   switchgear without requiring a less-than-specified cable bending radius. Feeder cable
   properties are described elsewhere in the Contract Documents.

B. Cable compartment shall permit cable entrance from top or bottom.

C. Provisions shall be made to accommodate the number and size of DC positive cables as
   indicated with additional four spares in each feeder breaker section.

D. Provide for the termination to accommodate the number and size of DC negative return
   cables as indicated with additional four spares on load side of the negative disconnect
   switch.

2.08 PROTECTIVE DEVICES

A. General Requirements:
   1. Protective relays provided in DC switchgear shall be Intelligent Electronic Devices
      (IED) equipped with communication function which shall communicate with
      substation Localized Central Monitoring System (LCMS) and SCADA, and shall be
      similar in function and appearance to those provided for Sound Transit South Link.
   2. Control, measurement and fault recording function shall be built into protective
      relays installed in DC switchgear.
3. Refer to Section 34 21 16.23, TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices, for detailed hardware and software requirements of IEDs. Basic functions and indications shall be via LCD screens located on the IEDs for each DC main and feeder circuit breaker.

4. Provide wire, and connect protective relays and devices as indicated on the Contract Drawings.

5. Provide additional components such as auxiliary relays, isolating diodes, and similar devices not shown in the Contract Drawings, but required for a complete installation.

6. Avoid wiring congestion.

7. Arrangement and Appearance:
   a. Arrange devices such as auxiliary relays, indicating lights and test plugs to be conveniently accessible and easily visible.
   b. The grouping shall be modular and place related functions in proximity.
   c. Mount devices plumb and square with the lines of the panels and mount as recommended by the manufacturer and approved by Resident Engineer.
   d. Auxiliary devices shall match the general appearance as far as possible with frames of a compatible approved color and finish.
   e. Devices of the same general type shall be manufactured by the same company and shall be similarly arranged and mounted.

B. Refer to substation one-line diagram in the Contract Drawings for arrangement of protective relays and devices.

C. Additional protective functions/devices recommended by Contractor or equipment manufacturers may be installed with Sound Transit approval.

D. At a minimum, provide the protective functions/devices described below, as shown on the substation one-line diagram in the Contract Drawings.

E. Overcurrent. As a minimum, the following overcurrent protection functions shall be provided:

1. Instantaneous Overcurrent Trip:
   a. Trip Threshold (inst): 0.3 to 9 PU.
   b. Trip Delay (Inst Del): 0 to 250 milliseconds.

2. Low Level Fault Trip:
   a. Trip Threshold (ILLF): 0.05 to 5 PU.
   b. Trip Delay (LLFDel): 0.5 to 99 minutes.

3. Timed Overcurrent Trip:
   a. Trip Threshold (Itmd): 0.2 to 2.5 PU.
b. Time Delay (TmdDel): 0.1 to 150 sec.

c. Provide timed overcurrent trip function with inverse time characteristic that can be graphed with the set current, Itmd, as the y-axis, and the time delay, TmdDel, as the x-axis.

d. Tripping shall be initiated when the load current exceeds the set current during the period of time t such that (t / TmdDel) and (Iload / Itmd) correspond to a point on the curve.

4. Rate of Rise Trip:
   b. Current Rise Limit (I): 0.1 to 2 PU.
   c. Delay Time (Delay): 20 to 400 milliseconds.
   d. Rate of rise trip shall be initiated if all of the following conditions are met:
      1) Current di/dt exceeds the trip limit, di/dt.
      2) di/dt stays above the trip limit during the delay time, Delay.
      3) During the delay time current exceeds the current rise limit.

5. Reverse overcurrent protection: All overcurrent protection functions shall operate for reverse currents.

F. Load Measure and Reclosure:

1. Provide each DC feeder cubicle with a set of automatic reclosing functions and equipment, including the following:
   a. Load measuring function (Device 82).
   b. Adjustable time delay reclosing function (Device 83).
   c. Load measuring resistors mounted on the top of the circuit breaker cubicle;
   d. Associated accessories.

2. Initiate the load measuring and automatic reclosing cycle when either the DC circuit breaker receives a "close" command (from the local or remote control), or when the circuit breaker is tripped automatically and attempts to reclose.

3. A "lockout" status of the DC lockout relay shall disable the load measuring and automatic reclosing cycle.

4. Precede initiation of the load measuring cycle by an adjustable time delay to permit the faulted line section to become fully deenergized.

5. At the commencement of the load measurement cycle, a voltage sensor shall determine whether there is no voltage on the section.

6. If the voltage measuring circuit detects potential on the section, it shall reclose the associated circuit breaker immediately, providing that this potential is greater than a preset value.
a. The pickup setting shall be adjustable over the range of 1200 to 1500 Vdc.
b. Initially the pickup voltage shall be set to 1400 Vdc.

7. If the voltage measuring circuit detects no potential on the section, the load measuring function shall make repeated load measurements at suitable adjustable time intervals.

8. If a load measurement determines that no fault is present, initiate automatic reclosing of the circuit breaker.

9. A successful reclosure with no automatic trip within 5 seconds shall complete the measurement cycle and reset the devices to their initial state.

10. Make provision for selection of up to six attempts to complete a successful load measurement and automatic reclosing cycle at 15 second intervals, within a 3 minute period. Initial setting of reclosure device shall be set at 3 reclosure attempts.

11. If no successful reclosure takes place in the 3 minute period, the automatic reclosing and load measuring system shall time out the feeder breaker from closing.

12. Provide each automatic reclosing and load measuring function with test facilities that shall check the functioning of all devices.
   a. Initiate test cycle with a local "test" push-button which shall be functional only when the circuit breaker removable element is in the "test" position.
   b. Circuit breaker shall not close during an automatic reclosing and load measuring test when the breaker is in the "connected" position.

13. Monitor condition of reclosure device with indicating LEDs.

G. High Resistance Frame Fault:

1. Connect a high-resistance frame fault relay (Device 64G and H) between the structure and the ground mat. Relay shall be rated for 1500V.

2. Insulate DC switchgear enclosure from ground. Single-point ground enclosure through a separate high resistance ground relay device 64G & H by means of a 2.4kV insulated 4/0 AWG copper conductor connected directly to the substation ground mat.
   a. The 64G & H relay shall be the only ground path to the enclosure.
   b. Provide adjustable settings for annunciation/alarm and trip functions.
   c. The occurrence of any "Grounded Structure" or "Hot/Alive Structure" shall be detected. Trip function shall trip and lock out the substation and "Hot/Alive Structure" shall initiate the Transfer trip to adjacent TPSS

3. DC feeder breakers shall reclose after the main DC circuit breaker is opened, except when a frame fault occurs, the DC breakers lock out.

4. Main DC circuit breaker shall operate to isolate the Transformer-Rectifier Unit in case of an internal fault while allowing continuity of the overhead distribution system.
H. Incomplete Sequence (Device 48):
   1. This function shall detect the failure of a DC circuit breaker to clear a fault within a predetermined time.
   2. This function shall actuate the ac lock-out relay (Device 86) when actuated.
I. Transfer Trip: For transfer trip initiated by DC breakers or initiated by ETS/SSS, see Section 34 21 16.23, TE Substation LCMS and IED.
J. Reverse Current:
   1. Provide reverse current protection (Device 32A) for the main DC breaker.
   2. The protection shall detect current flow from the distribution bus into the rectifier unit and trip and lock out the main DC and ac circuit breakers.
   3. The trip level shall be initially set to 5 percent of the rated current or as approved by Resident Engineer.
K. 1500 V Shorted to 125 Vdc: Provide relay to detect 1500 Vdc shorted to 125 Vdc (Device 59) and annunciate the alarm to LCMS and SCADA and trip and lock out the main DC and ac circuit breakers.

2.09 INSTRUMENTS AND METERS
A. Accuracy of indicating instruments shall be within 1 percent of full-scale reading.
B. Main DC switchgear shall be provided with ammeter and voltmeter which shall be switchboard analog type:
   1. Cases: Dustproof, with an approved color and finish and covered with a non-reflecting glass window.
   2. Ammeter Scale: 0-4000A except as indicated.
   3. Voltmeter Scale: 0-2000 V.
C. DC feeder breakers shall be provided with ammeter and voltmeter which shall be switchboard analog type:
   1. Cases: Dustproof, with an approved color and finish and covered with a non-reflecting glass window.
D. Ammeter Scale: 0 to + 4000 0 to - 4000A, 0 being center scale except as indicated:
   1. Voltmeter Scale: 0-2000 V.
E. Instruments for measuring DC values shall receive their inputs from isolation converters that shall be provided within the bus compartment of the switchgear:
   1. Provide auxiliary devices required for operation of the converters.
   2. Provide suitable isolation and insulation in order to ensure safe operation in contact with personnel.
2.10 MIMIC BUS

A. Provide mimic bus across the entire front of the switchgear complying with mimic bus requirements in Section 3421 19.13, Medium-Voltage Ac Circuit Breaker Switchgear.

PART 3 - EXECUTION

3.01 INSTALLATION

A. The switchgear shall be installed in accordance with Section 34 21 16.25, Traction Power Substation Installation.

B. Completely insulate DC switchgear enclosure and rectifier from ground and from the traction power transformer and the ac switchgear:

1. Insulate and isolate DC switchgear and rectifier from the floor using an epoxy floor covering in accordance with Section 09 67 25, Dielectric Epoxy Flooring.

2. Insulate and isolate DC switchgear and rectifier from the transformer using electrical laminate in accordance with Section 34 21 16.25, Traction Power Substation Installation.

3.02 FIELD QUALITY CONTROL

A. Field Tests and Inspections: Perform field acceptance test in accordance with Section 34 21 16.11, Traction Power and Substation Testing.

3.03 PROTECTIVE DEVICE COORDINATION

A. Establish final setting of relaying systems and protective devices during the systems and acceptance tests specified in Section 34 21 16.11, Traction Power and Substation Testing.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. Section Includes:
      1. Products fabricated by the Contractor or custom manufactured by its suppliers.
      2. Galvanizing.
      3. Welding.
      4. Shop-applied powder coat.
      5. Shop-applied paint coating system.

1.02 DEFINITIONS
   A. Galvanneal: Zinc-iron alloy coating created on sheet steel by a continuous hot-dipping process followed by heat treatment in an annealing furnace.
   B. Hot-dip galvanizing: Dipping steel members and assemblies into molten zinc for long-term corrosion protection. Resultant zinc coating fuses permanently with base steel material.

1.03 REFERENCE STANDARDS
   A. Section incorporates by reference the latest revisions of the following documents:
      1. American Society for Nondestructive Testing (ASNT):
         b. ASNT-TC-1A - Personnel Qualification and Certification in Nondestructive Testing.
      2. American Welding Society (AWS):
         a. AWS A5 Series - Filler Metal Specifications.
         c. AWS D1.1/D1.1M - Structural Welding Code – Steel.
         d. AWS D1.3/D1.3M - Structural Welding Code – Sheet Steel.
         e. AWS QC1 - Standard for AWS Certification of Welding Inspectors.
         f. AWS QC7 - Standard for AWS Certified Welders.
3. ASTM International (ASTM):
   e. ASTM A384/A384M - Standard Practice for Safeguarding Against Warpage and Distortion During Hot Dip Galvanizing of Steel Assemblies.
   f. ASTM A385/A385M - Standard Practice for Providing High-Quality Zinc Coatings (Hot Dip).
   g. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
   h. ASTM A780/A780M - Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings.
   l. ASTM D610 - Test Method for Evaluating Degree of Rusting on Painted Steel Surfaces.
   m. ASTM D714 - Test Method for Evaluating Degree of Blistering of Paints.
   r. ASTM D2485 - Standard Test Methods for Evaluating Coatings For High Temperature Service.


v. ASTM D3363 - Standard Test Method for Film Hardness by Pencil Test.


hh. ASTM E164 - Standard Practice for Contact Ultrasonic Testing of Weldments.


II. ASTM G151 - Standard Practice for Exposing Nonmetallic Materials in Accelerated Test Devices that Use Laboratory Light Sources.


4. Society for Protective Coatings (SSPC):
   a. SSPC-PA 1 - Shop, Field, and Maintenance Painting of Steel.
   b. SSPC-PA 2 - Procedure for Determining Conformance to Dry Coating Thickness Requirements.
   c. SSPC-SP6 - Commercial Blast Cleaning.
   d. SSPC-SP8 – Pickling.
   e. SSPC-Paint 36 - Two-Component Weatherable Aliphatic Polyurethane Topcoat, Performance Based.
   f. SSPC-Paint 42 - Epoxy Polyamide/Polyamidoamine Primer, Performance Based.

1.04 SUBMITTALS

A. Submit each item listed below as a complete package.

B. Shop-Applied Galvanizing Certification:
   1. If more than one galvanizer is used, include the items listed below for each galvanizer.
   2. Certification:
      a. Certification of membership in American Galvanizers Association, signed by the galvanizer.
      b. Notarized certificates of compliance with ASTM preparation and galvanizing requirements specified in this Section.
      c. Certification that galvanizing is in conformance with this Section, signed by the galvanizer.

C. Welding Design Package:
   1. Certification:
      a. Furnish notarized certificates of compliance with ASTM requirements specified in this Section.
   2. Welder Qualifications:
      a. Submit record of AWS qualification for each welder to be employed in the Work.
      b. Submit certified copies of qualification test records for each welder, welding operator and tack welder to be employed in the Work.
c. Submit welders’ identification marks (I.D.) for each welder along with qualifications.

3. Welding Procedures:
   a. Before welding, submit the procedure that will be used for qualifying welding procedures.
   b. For procedures other than those prequalified in accordance with AWS D1.1/D1.1M, submit a copy of procedure qualification test records in accordance with the qualification requirements of AWS D1.1/D1.1M.
   c. If field welding is permitted, submit descriptive data for field welding equipment.

D. Shop-Applied Powder Coat Design Package:
   1. Qualifications (for each applicator):
      a. Evidence that powder coat applicator has experience with the substrate.
      b. Evidence that the applicator is an approved and authorized applicator of the coating formulator's products.
      c. Applicator's quality control procedures.
      d. Certification that the applicator has been authorized to provide the coating formulator's warranty.
   2. Product Data:
      a. Descriptive and technical data sheets describing products proposed for use.
      b. Documentation of application process, including preparation before coating.
   3. Powder Coat Samples:
      a. Submit for each color and substrate one 12-inch square of the substrate to which powder coat will be applied with the primer, top coat, and graffiti coat applied.
      b. Stagger each coat such that the Resident Engineer can view each.
   4. Repair: Manufacturer recommended repair procedures and materials procedures for field touch up of marred or damaged coatings using air-drying spray materials in matching colors.
   5. Maintenance Information: Manufacturer's recommended maintenance materials and procedures.

E. Shop-Applied Paint Coating System Design Package:
   1. Qualifications:
      a. Evidence that paint coating applicator has experience with the proposed paint coating system.
b. Certification that the applicator has been authorized to provide the coating formulator's warranty.

2. Product Data:
   a. Performance characteristics: For each substrate used, the tested performance characteristics of the coating.
   b. Documentation of application process.

3. Paint Coating System Samples:
   a. Submit for each color and substrate one suitably sized sample of the substrate to which paint coating system will be applied with the primer, top coat, and graffiti coat applied.
   b. Stagger each coat such that the Resident Engineer can view each.

F. Shop Galvanizing Source Inspection and Test Records:
   1. Submit records for each specified inspection and test immediately after inspections and tests are completed.
   2. If shop galvanizing repairs are required, submit detailed records, including photos, documenting areas repaired, procedures used, and inspections and tests performed after completion of the repair.

G. Shop Welding Inspection and Test Records:
   1. Submit records for each specified inspection and test immediately after inspections and tests are completed.
   2. If shop welding repairs are required, submit detailed records, including photos, documenting welds repaired, procedures used, and inspections and tests performed after completion of the repair.

H. Shop-Applied Powder Coat Certification and Test Records:
   1. Certification that the applied powder coat is in conformance with this Section and the approved Design Package, signed by the applicator.
   2. Test records showing compliance with testing and performance requirements specified in this Section.
      a. Test records may be existing, if substrate and product are identical to that used for this project.
      b. If no existing test records are available, perform each specified test and submit results.

I. Shop-Applied Paint Coating System Certification and Test Records:
   1. Certification that the applied paint coating system is in conformance with this Section and the approved Design Package, signed by the applicator.
   2. Test records showing compliance with testing and performance requirements specified in this Section.
a. Test records may be existing, if substrate and product are identical to that used for this project.

b. If no existing test records are available, perform each specified test and submit results.

J. Galvanizing Field Repair Procedure:
   1. If repair is necessary, submit a detailed step-by-step repair procedure before performing repairs.

K. Field Welding Test Report:
   1. If field welding is performed, submit as follows:
      a. Records for each specified inspection and test immediately after inspections and tests are completed.
      b. If field welding repairs are required, submit detailed records, including photos, documenting welds repaired, procedures used, and inspections and tests performed after completion of the repair.

L. Shop Applied Coatings Field Repair Procedure:
   1. If repair is necessary to shop-applied powder coat or shop-applied paint coating system, submit the following before performing repairs:
      b. Specified repair sample after specified salt spray testing has been completed.

1.05 QUALITY ASSURANCE

A. Single Source for Galvanized and Finished Metal Fabrications:
   1. Use products of one manufacturer on each specific item to ensure exact color match and finish appearance.

B. Galvanizing:
   1. Galvanizing firm shall be member of American Galvanizers Association Inc. (AGA).
   2. Inspection and Tests:
      a. Inspections, test and samples shall conform with ASTM Specifications and Standards.
      b. Inspection rights and privileges, procedures and acceptance or rejection of galvanized steel materials shall conform with ASTMA123/A123M.

C. Welding:
   1. Welder Qualifications:
a. Welding shall be done by AWS certified, qualified welders who make only those welds for which they have been qualified in accordance with AWS, or other approved qualifying procedures.

b. Welders, welding operators, and tack welders shall be certified in accordance with AWS QC7 and AWS D1.1/D1.1M.

c. For sheet steel, welders shall be certified in accordance with AWS QC7 and AWS D1.3/D1.3M, Qualification Section.

d. Records of welder qualification tests shall be made available for review upon the Resident Engineer's request.

2. Welding Procedure Qualification:

a. Welding procedures shall be prequalified or qualified in accordance with AWS D1.1/D1.1M.

b. For sheet steel, proposed welding procedures shall be qualified in accordance with AWS D1.3/D1.3M. Prequalification is not applicable to sheet steel.

3. Welding Inspector Qualifications:

a. Welds to be inspected by the Contractor shall be inspected and certified by an AWS Certified Welding Inspector (CWI).

b. CWI shall be certified in accordance with AWS QC1.

4. Nondestructive Testing Personnel Qualifications:

a. Qualified and certified in accordance with SNT-TC-1A and ASNT CP-105.

b. Certified for NDT Level I and working under a person or persons certified for NDT Level II or Level III.

5. Welding Records:

a. Retain mill certificates and certified copy of reports for analyses and tests required by referenced ASTM and AWS specifications.

b. Retain radiographs upon completion of fabrication.

c. Retain certifications that magnetic particle and dye-penetrant inspections have been satisfactorily completed.

D. Shop-Applied Powder Coating:

1. Applicator Qualifications:

a. Engage an experienced coating applicator with experience in properly applying the coating on the specified substrate.

b. Applicator shall have quality control procedures firmly established in its shop.

c. Resident Engineer may, at his option, visit the applicator's facility to confirm adherence to quality control procedures.
1.06 DELIVERY, STORAGE, AND HANDLING
A. Deliver, handle, and store metal fabrications in a manner that prevents damage to the item, its galvanizing, and its finish.

1.07 WARRANTY
A. Scope: Warranty applies to the following:
   1. Coating applied to shop welds.
   2. Shop-applied powder coat.
   3. Shop-applied paint coating system.
B. Warranty Period: 10 years.
C. Furnish written warranty stating that coating will not blister, peel, crack, chalk, change color or have other forms of degradation during warranty period.
D. Coating failure:
   1. In the event that coating failure occurs within warranty period, replace item indicating coating failure, including full cost of labor and materials for such replacement.
   2. Replacement items shall be new and finished with same type coating meeting requirements of this Section.
   3. Replacement items shall match adjacent members.
E. The Resident Engineer may permit field repairs in lieu of replacement, provided coating failure is minor in scope and field repair material and method employed match its adjacent member. Repairs shall be compatible with original surface.

PART 2 - PRODUCTS
2.01 SHOP-APPLIED GALVANIZING
A. General:
   1. Wherever materials are called out as “hot-dip galvanized” or “galvanized,” provide a zinc coating after fabrication in accordance with ASTM A123/A123M.
   2. Hardware items such as bolts or other threaded fasteners shall be hot-dip galvanized after fabrication in accordance with A153/A153M.
   3. Specified materials or products that are not readily available in the specified hot-dip finish, shall be custom hot dipped after manufacture by an independent galvanizer.
B. Selection, Design, and Fabrication Before Galvanizing:
   1. Verify with supplier or fabricator that material is chemically suitable for galvanizing.
2. Warpage: Design assemblies as recommended in ASTM A384/A384M to limit warpage and distortion during hot-dip galvanizing.
   a. Notify the Resident Engineer of potential warpage problems that require modification in design before proceeding with steel fabrications.
   b. Costs for alternative designs shall be performed at no additional cost to Owner.

3. Design and fabricate assemblies requiring shop fabrication using methods recommended in ASTM A385/A385M to obtain high quality hot-dip galvanized coating.

4. Embrittlement: Select proper steel, design assemblies, and thermally treat before galvanizing as recommended in ASTM A143/A143M to withstand normal galvanizing operations without embrittlement.

5. Galvanizer Coordination Drawings: Furnish shop drawings to galvanizer of non-standard fabrications, tubular fabrications, and fabrications with materials of different thicknesses.

6. Inspect iron and steel hardware before galvanizing and verify suitability for galvanizing. Replace items that are not suitable for galvanizing.

7. When the item to be galvanized incorporates threaded assemblies, make provisions in thread size to accommodate galvanizing and galvanize disassembled.

8. Weld, drill, and assemble galvanized members before galvanizing.

C. Preparation:
   1. Remove welding slag, splatter, and burrs.
   2. Clean surfaces in conformance with SSPC SP6, Commercial Blast Cleaning.
   3. Pickle surfaces in conformance with SSPC SP8, Pickling.
   4. Safeguard against increasing the likelihood of steel embrittlement during pickling in accordance with ASTM A143/A143M.
   5. Mask galvanized members that are to be field or shop welded after galvanizing to a distance of 1 inch from weld line before galvanizing.

D. Hot-Dip Galvanizing:
   1. Select a galvanizer with galvanizing kettle large enough to accommodate the largest member or assembly requiring hot-dip galvanizing. Progressive dipping shall not be used.
   2. Hot-dip galvanize structural steel and metal fabrications as indicated in conformance with ASTM A123/A123M.
   3. Hot-dip galvanize bolts or other threaded fasteners after fabrication in accordance with A153/A153M.
   4. Thickness of zinc coating: Conform to requirements of ASTM A123/A123M or ASTM A153/A153M, whichever is applicable.
5. Finish, uniformity, and adherence of coating: Conform to requirements of ASTM A123/A123M or ASTM A153/A153M, whichever is applicable.

6. Galvanized members on which powder coat or paint will be applied shall not be quenched by the galvanizer.

7. Galvanizer’s Stamp: Galvanized materials shall be marked with the galvanizer’s stamp.

E. Mechanical Galvanizing shall not be used.

2.02 WELDING

A. Weldability of Steel: For structural steel requiring impact test qualification and for corrosion resistant structural steel, establish weldability of steel and procedures for welding it by qualification in accordance with AWS D1.1/D1.1M, to match the notch toughness and weathering characteristics of the base metal.

B. Rod/Electrodes:

1. Electrodes for structural plate, shapes, pipe, tubes, and bars shall conform to AWS A5 Series Standards and shall be coated rods or wire of size and classification number as recommended by their manufacturers for the conditions of actual use.

2. Electrodes for sheet steel shall conform to AWS A5 Series Standards and shall be coated rods or wire of size and classification number, as recommended by their manufacturers for the conditions of actual use.

C. Stud Shear Connectors: Only products of manufacturers qualified in accordance with AWS D1.1/D1.1M will be accepted for this Work.

D. Shop Welding:

1. Perform shop welding as indicated in accordance with AWS D1.1/D1.1M, and AWS D1.3/D1.3M, as applicable to the Work.

2. Welders shall mark adjacent to completed welds their welder I.D., using metal stamp, metal engraving, keel, paint stick, or other appropriate marking material.

E. Field Welding:

1. Field welding shall not be performed without approval of the Resident Engineer.

2. If approved by the Resident Engineer, field welding shall comply with applicable AWS standards, as proposed by the Contractor and approved by the Resident Engineer.

F. Coating Shop Welds:

1. Coat shop welds made after hot-dip galvanizing and areas masked to permit welding as follows:
   a. Provide an inorganic ethyl silicate primer containing 85 percent zinc by weight in the dry film.
   b. Prepare surface in strict compliance with manufacturer’s recommended procedures.
c. Apply a single coat of 75 microns dry film thickness in strict accordance with manufacturer’s application instructions.

d. Top coat is required only if surrounding surface is painted, or if necessary to match color of surrounding area.

e. Where top coating is required, provide a compatible product and apply according to manufacturer’s instructions to achieve good cohesion and prevent pinholing.

2. Color: Match color of surrounding area.

2.03 SHOP-APPLIED POWDER COAT

A. Powder Coat System:

1. Powder Coat: Polyester triglycidyl isocyanurate (TGIC), thermoset color finish system based on dry, powdered resins.

2. Primer: Compatible with powder top coat, as confirmed by powder coat manufacturer.

3. Top Coat: Compatible with powder primer, as confirmed by powder coat manufacturer.

4. Anti-Graffiti Coating:
   a. Permanent protection system designed to withstand numerous clean-ups.
   b. Suitable for cleaner available in the United States.
   c. Compatible with powder coat.

5. Dry Film Thickness: As recommended by coating manufacturer; minimum thickness of primer and top coat 4 mils.

6. Powder coat system shall include primer, top coat, and graffiti coat, and meet the following requirements:
   a. As listed below in the Article titled “Source Quality Control” in the Paragraph titled “Shop-Applied Powder Coating Testing,” when applied on the specified substrate, e.g. hot dip galvanized steel or galvannealed sheet steel.
   b. Warranty requirements specified above.

B. Perform mechanical processing such as sawing, drilling, milling, cutting, and bending before applying shop applied coatings.

C. Preparation before coating:

1. Hot-dip galvanized per ASTM A123/A123M: Prepare surface in accordance with ASTM D7803.


3. Cleaning:
a. Clean surfaces to be coated as follows:

1) Remove all dust, dirt, and other surface debris by vacuuming, wiping dry with clean clothes or compressed air.

2) Rinse scrubbed surfaces with clean water until foreign matter is flushed from surface.

3) Allow surfaces to drain completely and allow to thoroughly dry.

4) Use water blasting only when necessary for extreme cases of contamination by oily residue and where hand washing is impractical.

5) If the above procedures do not clean the substrate surfaces, clean the surfaces with high pressure water washing.

4. Pretreatment:

   a. Wash parts in a four stage iron-phosphate washer for steel or zinc-phosphate washer for galvanized steel, or in accordance with coating manufacturer’s recommendations.

   b. Dry parts before application of power coating.


D. Application:

   1. Edges: Treat and finish as required to ensure specified minimum dry film coating thickness is achieved. Precoating of edges maybe required.

   2. Apply primer in accordance with manufacturer’s written application instructions.

   3. Apply top coat in accordance with manufacturer’s written application instructions.

   4. Allow surfaces to cure for time period in accordance with manufacturer’s cure curves.

   5. Inspect parts after cooling.

E. Color:

   1. TPSS Enclosure Exterior: Color will be provided by the Resident Engineer.

   2. TPSS Enclosure Interior: RAL 9010, Pure White.


2.04 SHOP-APPLIED PAINT COATING SYSTEM

A. General Requirements:

   1. Coatings shall be certified VOC compliant and conform to applicable regulations and EPA standards.

   2. Material Compatibility:
a. Provide primers, finish coat and anti-graffiti materials and related materials that are compatible with one another and the steel substrate.
b. Furnish documentation from manufacturer demonstrating compatibility in both application and service based on testing and field experience.

3. Material Quality:
   a. Provide highest grade of coatings as regularly manufactured by acceptable coating manufacturers.
b. Materials not displaying manufacturer's identification as a best-grade product will not be acceptable.

4. Coating system shall meet the requirements listed below in the Article titled "Source Quality Control" in the Paragraph titled "Shop-Applied Paint Coating System Testing," when applied on the specified substrate, e.g. hot dip galvanized steel or galvannealed sheet steel.

B. Primer: Polyamide epoxy, 4-6 mils dry film thickness.

C. Top Coat:
   1. High solids, pigmented, aliphatic polyurethane, meeting requirements of SSPC Paint 36.
   2. Dry film thickness: Minimum 4 mils.
   3. Color: As specified, as indicated, or as directed by the Resident Engineer.
   4. Gloss: Flat, semi-gloss, or gloss, as specified. Textured finishes not permitted.

D. Anti-Graffiti Coat:
   1. Clear, aliphatic polyurethane non-sacrificial coating designed to resist graffiti and protect the underlying substrate.
   2. From the same manufacturer and compatible with approved top coat.

E. Acceptable Manufacturers/Brands:
   2. Carboline.
   3. PPG Protective and Marine Coatings.
   4. Tnemec; or approved equal.

F. Shop-Applied Paint Coating Application:
   1. Prepare steel in accordance with paint manufacturer’s recommendations.
      a. Verify with paint manufacturer that proposed surface cleaner is compatible with approved paint coating system.
      b. Apply paint as soon as possible after surface preparation.
   2. Primer:
a. Shop-apply in accordance with SSPC-PA 1, SSPC-PA 2, SSPC-Paint 42, and manufacturer’s instructions.

b. Verify dry film thickness in accordance with SSPC-PA 2.

3. Top coat: Shop-apply in accordance with manufacturer’s instructions.

4. Graffiti coat: Shop apply two coats in accordance with manufacturer’s instructions.

2.05 SOURCE QUALITY CONTROL

A. Shop Inspections and Tests by the Resident Engineer:

1. Galvanizing, shop applied coatings, and welds are subject to inspections and tests by the Resident Engineer.

2. If testing is performed by the Resident Engineer, the test results will be available to the Contractor.

B. Galvanizing:

1. Shop Galvanizing Inspection and Test:

   a. Inspect and test galvanizing at galvanizer’s facility for full coverage and adhesion to steel in accordance with ASTM A123/A123M or ASTM A153/A153M, whichever is applicable.

   b. Inspection and test shall include the following:

      1) Visual examination of samples and finished products.

      2) Tests to determine weight or mass of zinc coating per square foot of steel surface.

      3) Tests to determine distribution and uniformity of zinc coating.

      4) Tests to determine thread fittings of units, washers to bolts.

   c. Test hardware or assemblies susceptible to embrittlement in accordance with ASTM A143/A143M. The Resident Engineer will make the final determination on whether embrittlement testing is required.

   d. Shop Galvanizing Repair:

      1) Grind rough areas to produce a uniform surface.

      2) Repair steel grinding, scratches and other damage, in accordance with ASTM A780/A780M.

      3) Sprayed Zinc: Clean and preheat to assure freedom from loose material, moisture, oil grease, or other foreign matter before applying zinc. Apply zinc coating by metallizing spray to clean and dry surfaces.

      4) Zinc-Based Solders and Wire:

         a) Clean to remove loose material and contaminates, and heat to approximately 572 degrees F.
b) Apply zinc-alloy repair compound by spreading material over heated surface in accordance with compound manufacturer’s instructions.

c) Remove repair compound residues with damp cloth or by rinsing with water.

2. Dry film thickness of applied repair materials: Not less than galvanized coating thickness required by ASTM A53/A53M, A123/A123M, or A153/A153M.

C. Shop Welding Inspections and Tests by the Contractor:

1. Visual Inspection:
   a. Visually examine all welds in accordance with AWS D1.1/D1.1M.
   b. Quality of welds and standards of acceptance shall be in accordance with AWS D1.1/D1.1M.

2. Inspection and Testing Type Requirements:
   b. Liquid Penetrant Inspection: Liquid dye penetrant inspection of welds shall conform to ASTM E165/E165M.
   c. Magnetic Particle Inspection: Magnetic particle inspection of welds shall conform to ASTM E709.
   d. Ultrasonic Testing: Comply with AWS D1.1/D1.1M and ASTM E164, as applicable.
   e. Radiographic Testing: Comply with AWS D1.1/D1.1M, ASTM E94, and ASTM E1032, as applicable.

3. Inspect complete and partial joint penetration groove welds and fillet welds using magnetic particle inspection as follows:
   a. One out of five (20 percent) of complete joint penetration groove welds of tee and corner joints.
   b. One out of ten (10 percent) of partial joint penetration groove welds and fillet welds.

4. Random Testing: Randomly test 10 percent of welds by either liquid penetrant inspection or magnetic particle inspection.

5. Additional Testing: If random testing reveals possible flaws, test the welds in question, and additional welds if directed by the Resident Engineer, using ultrasonic or radiographic testing. Requirement for this additional testing shall be at no additional cost to the Owner and shall be at the sole discretion of the Resident Engineer.

6. Test complete joint penetration groove welds by radiographic testing as follows:
   a. One out of ten (10 percent) with thickness equal to or less than 3/4 inch.
b. One out of two (50 percent) with thickness greater than 3/4 inch and equal to or less than 1.5 inches.

c. 100 percent for thickness greater than 1.5 inches.

d. Complete joint penetration groove welds not accessible for radiographic testing shall be subjected to ultrasonic testing. The extent shall be the same as specified for radiographic testing.

7. Repairs:

a. Repair unacceptable welds in accordance with AWS D1.1/D1.1M.

b. Reinspect or retest repaired or corrected welds as specified for the original weld.

D. Shop-Applied Powder Coat Testing:

1. Coating shall meet or exceed the following testing requirements and performance criteria of ASTM D3451 and other standards indicated below.

2. Physical Properties of Powder Coatings:


c. Adhesion: ASTM D3359, Method B, 5B.

d. Elongation (flexibility): Mandrell Bending Test, ASTM D522/D522M, equal to or greater than 3 mm.

e. Household chemical resistance: ASTM D1308.


g. Chip resistance: ASTM D3170.

h. Gloss:

1) Interior: 25 to 40 percent reflective gloss.

2) Exterior: ASTM D523, 80 to 90 plus.

3) Surface: Smooth

i. Pencil hardness:

1) Interior: ASTM D3363, F minimum.

2) Exterior: ASTM D3363, 4H (minimum).


4. Accelerated Environmental Exposure:

a. Salt spray:
1) Interior: ASTM B117, 250 hours, maximum undercut failure of 1.6 mm at scribed test lines; no blistering.

2) Exterior: ASTM B117, 500 hours, maximum undercut failure 1 mm; no blistering.

b. Humidity Resistance: ASTM D2247, 500 hours, maximum undercutting 1 mm; no blistering.

E. Shop-Applied Paint Coating System Testing:

1. Primer shall meet or exceed the following testing requirements and performance criteria of the standards indicated below:

   a. Abrasion Resistance per ASTM D4060 (CS17 Wheel, 1,000 grams load), 1 kg Load: 200 mg loss.

   b. Adhesion per ASTM D4541: 1050 psi.

   c. Corrosion Weathering per ASTM D5894, 13 Cycles, 4,368 Hours: Rating 10 per ASTM D714 for blistering; Rating 7 per ASTM D610 for rusting.


   e. Flexibility per ASTM D522/D522M, 180 degree Bend, 1 inch Mandrel: Passes.

   f. Pencil Hardness per ASTM D3363: 3B.

   g. Moisture Condensation Resistance per ASTM D4585, 100 degrees F, 2000 Hours: Passes, no cracking or delamination.

   h. Dry Heat Resistance per ASTM D2485: 250 degrees F.

2. Top Coat shall meet or exceed the following testing requirements and performance criteria of the standards indicated below:

   a. Abrasion Resistance per ASTM D4060, CS17 Wheel, 1,000 Cycles 1kg Load: 87.1 mg loss.

   b. Adhesion per ASTM D4541: 1050 psi.

   c. Direct Impact Resistance per ASTM D2794: Greater than 28 inch pounds.

   d. Indirect Impact Resistance per ASTM D2794: 12-14 inch pounds.

   e. Dry Heat Resistance per ASTM D2485: 200 degrees F.

   f. Salt Fog Resistance per ASTM B117 9,000 Hours: Rating 10 per ASTM D714 for blistering.

   g. Flexibility per ASTM D522/D522M, 180 Degree Bend, 1/8 Inch Mandrel: Passes.

   h. Pencil Hardness per ASTM D3363: 2H.

   i. Moisture Condensation Resistance per ASTM D4585, 100 degrees F, 1000 Hours: No blistering or delamination.
j. Xenon Arc Test per ASTM D4798/D4798M: Pass 300 hours.

PART 3 - EXECUTION

3.01 INSTALLATION
A. Field Welding: Shall be performed as specified for shop welding.

3.02 SITE QUALITY CONTROL
A. Galvanizing: After delivery of substation, inspect galvanizing and repair if damaged.
   1. Repair scratches and other damage in accordance with ASTM A780/A780M.
   2. If the following is performed in the field, repair in accordance with ASTM A780/A780M:
      a. Cutting metal.
      b. Grinding metal.
      c. Welding.
   3. Dry film thickness of applied repair materials: Not less than galvanized coating thickness required by ASTM A53/A53M, A123/A123M, or A153/A153M.
B. Welding Inspections and Tests:
   1. Perform tests of field welds as specified for shop welds.
C. Shop Applied Coating: After delivery of substation, inspect and repair damage to shop applied coatings.
   1. Repair minor film scratches and other blemishes in film surfaces in accordance with coating manufacturer’s recommended procedures and materials.
   2. Prepare a repair sample that matches the existing substrate, coating, and damage, with repair applied in accordance with the repair procedure, and subject to salt spray test per ASTM B117.
   3. Finished repairs shall match original finish for color and gloss, shall adhere to original finish, and shall exhibit no removal of coating film or blistering during dry adhesion testing when tested in accordance with ASTM D3359.
   4. Remove coated items damaged beyond repair and replace with newly fabricated and coated items.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes.
1. Medium-voltage single-conductor 26kV and 12 kV AC cable, supports, splices, terminations, and grounding.

1.02 REFERENCES

A. Definitions.
1. Medium-voltage cable: A single or multi-conductor insulated cable rated more than 2000 V

B. Reference Standards.
1. Section incorporates by reference the latest revisions of the following documents
2. ASME
   a. ASME NQA-1 Quality Assurance Requirements for Nuclear Facility Applications
3. Association of Edison Illuminating Companies (AEIC)
   a. AEIC CS8 Specification for Extruded Dielectric Shielded Power Cables Rated 5 Through 46 kV
4. ASTM International (ASTM)
   a. ASTM B8 Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
   b. ASTM B496 Specification for Compact Round Concentric-Lay-Stranded Copper Conductors
   a. 10 CFR 50, Appendix B Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants
6. Institute of Electrical and Electronics Engineers (IEEE)
b. IEEE 400-2 IEEE Guide for Field Testing of Shielded Power Cable Systems Using Very Low Frequency (VLF) (less than 1 Hz)

c. IEEE 404 IEEE Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV

d. IEEE 1202 IEEE Standard for Flame-Propogation Testing of Wire and Cable


7. International Cable Engineering Association (ICEA)

   a. ICEA S-97-682 Standard for Utility Shielded Power Cables Rated 5 Through 46kV

8. International Electrical Testing Association (NETA)

   a. NETA ATS Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

9. National Fire Protection Association (NFPA)

   a. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems

10. National Electrical Manufacturers Association (NEMA)

   a. NEMA WC 71 Nonshielded Cables Rated 2001-5000 V for Use in the Distribution of Electric Energy

   b. NEMA WC 74 5-46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy

11. Underwriters Laboratories (UL)

   a. UL 1072 Medium-Voltage Power Cables

   b. UL 1685 Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables

1.03 SUBMITTALS

A. Submit Product Data on the following items:

1. Medium-voltage single-conductor cable

2. Splicing, connecting, and terminating materials

B. Product information for each type and size of wire and cable shall include the following:

1. Complete electrical ratings for wire and cable.

2. Manufacturer of the wire and cable and location where cable is manufactured

3. Number and size of strands composing each conductor

4. Conductor insulation and shielding composition and thickness
5. Average overall diameter of finished wire and cable
6. Storage instructions
7. Minimum training radius, in inches, for both individual conductors within the cable and the multi-conductor cable itself
8. Pulling tension limits, in pounds
9. Sidewall pressure limits, in pounds per foot of bend radius
10. Instructions for stripping jacket, sheath, tape, binder, filler, and semiconducting insulation shield with minimum effort without damaging the insulation
11. Recommendations for installing, splicing and terminating conductors, shielding, ground wire and sheath

C. Submit Installation Plans:
1. 26 or 12kV Cable: Installation plan with detailed description of how cables are to be installed in raceways. Include details for protecting cable as it is placed in the raceway.

D. Submit Test Procedures, Results, and Reports:
1. Certified test reports for Flame Tests, Accelerated Aging Tests, Production Tests, and Final Tests
2. Test procedures for each test
3. Test results for each test a maximum of 10 days after date test was performed
4. Field Test Report, including the following:
   a. Continuity test
   b. Insulation resistance test
   c. Cable insulation tests

E. Field Service Engineer.
1. Submit for approval the name, title, and qualifications of the proposed manufacturer’s technical representative, referred to as the Field Service Engineer.
2. If the cable manufacturer proposes to utilize more than one person to carry out the required field services, provide the name, title, and experience qualifications of each person.
3. Prepare and submit a typewritten or word-processed report on the activities, observations, and findings for each field service visit. Submit reports within 15 Working Days of each visit.

1.04 QUALITY ASSURANCE / QUALITY CONTROL

A. Quality Assurance Program.
1. Cable shall be manufactured and tested under the control of a Quality Assurance program that meets the requirements of 10 CFR 50, Appendix B, as elaborated in ASME NQA-1, for materials traceability only.
B. Qualifications.

1. Cable: Cable shall have a performance record demonstrating a minimum of 30 years successful operating experience in transit, utility or industrial power applications for the insulation compound and conductor assemblies provided.

2. Installer Qualifications.
   a. Contractor shall provide personnel qualified in installation, splicing and termination of medium voltage cable. Personnel shall have direct experience with at least ten projects similar in scope and complexity with work shown on Contract Documents and specific to the cable being provided.

3. Cable Testing: Testing organization shall be NETA certified with a minimum of 10 years of experience in testing of medium-voltage power cables using Very Low Frequency (VLF) testing methods.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Comply with requirements in Section 26 05 00, Common Work Results for Systems Conductors and Cable, in Article titled “Delivery, Storage, and Handling.”

B. Reels and Marking: Cables shall be reeled, factory sealed and marked in accordance with AEIC CS8.

PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Comply with NFPA 130.

B. Conductors: Annealed, uncoated copper, round or compact, concentric-lay stranded per ASTM B8 or B496.

C. Insulation: Ethylene-propylene rubber (EPR) meeting electrical and physical requirements of NEMA WC 74, ICEA S-97-682, AEIC CS8, and UL 1072.
   1. EPR insulation shall be compounded by the cable manufacturer or submit evidence of minimum 40 years of continuous manufacture using the EPR compound currently in use.
   2. For flexibility, the insulation compound shall have an Apparent Bending Modulus of 2600 psi or less in accordance with Standard Test Method ASTM D747.

2.02 MEDIUM-VOLTAGE SINGLECONDUCTOR CABLE, 2.4 KV RATED

A. General.
   1. Type MV-90, 90 degrees C, unshielded, size as indicated
   2. Cable shall be suitable for use on service and feeders, indoors or outdoors, in wet or dry locations, or in raceway/duct. The cable shall be sunlight resistant, suitable for installation at 0 degrees C, and for installation in cable tray.
   3. Cables shall meet or exceed requirements of NEMA WC71 and UL 1072.
   4. See the Source Quality Control section, below, for flame test requirements.
B. Conductor Shield.
   1. Extruded semiconducting, thermosetting EPR applied directly over the conductor. Volume resistivity shall be no less than 10 or more than 1,000 ohm-meters at 90 degrees C.
   2. Shield shall strip cleanly from the conductor and be firmly bonded to the overlying insulation.
C. Insulation Level: 100 percent, unless indicated otherwise
D. Overall Sheath Jacket: Thermosetting low-smoke zero-halogen jacket
E. Acceptable Manufacturer and Product.
   1. The Okonite Company, Okoguard-Okoclear or approved equal.

2.03 MEDIUM-VOLTAGE SINGLE-CONDUCTOR CABLE, 5 KV AND ABOVE

A. General.
   1. Type MV-105, 105 degrees C, shielded, size as indicated
   2. Cable shall be suitable for use on service and feeders, indoors or outdoors, in wet or dry locations, or in raceway/duct. The cable shall be sunlight resistant, suitable for installation at 0 degrees C, and for installation in cable tray.
   3. Cables shall meet or exceed the requirements of ICEA S-97-682, NEMA WC 74, AEIC CS8, and UL 1072.
   4. See the Source Quality Control section, below, for flame test and accelerated aging test requirements.

B. Conductor Shield.
   1. Extruded semiconducting, thermosetting EPR applied directly over the conductor. Volume resistivity shall be no less than 10 or more than 1,000 ohm-meters at 90 degrees C.
   2. Shield shall strip cleanly from the conductor and be firmly bonded to the overlying insulation.
   3. Thickness of the conductor shield shall meet or exceed the requirements of AEIC CS8.
C. Insulation Level: 35 kV (for 26 kV system), 15kV (for 12kV system) 100 percent, unless indicated otherwise, meeting requirements of AEIC CS8
D. Insulation Shield.
   1. Extruded semiconducting, thermosetting EPR compound with a volume resistivity between 10 and 500 ohm-meters
   2. Insulation shield shall strip cleanly and have peel strength not less than 3 pounds or more than 18 pounds per 0.5-inch width. The insulation shield shall leave no conductive residue on the insulation after stripping.
   3. Thickness of the insulation shield shall meet or exceed the requirements of AEIC CS8.
E. Metal-tape Shield: Copper tape, 0.005 inch or greater in thickness, applied helically with a minimum of 12-1/2 percent overlap

F. Overall Sheath Jacket: Thermosetting zero-halogen, low-smoke jacket

G. Approved Manufacturer and Product
   1. The Okonite Company, Okoguard-Okolon or Okoguard-Okoclear; or approved equal.

2.04 2.4 KV POWER CABLE TERMINATIONS, TAPS AND SPLICES

A. Terminations.
   1. Terminals shall be long-barrel compression type. Compression tools shall apply a hexagonal compression using mechanical, electrical or hydraulic power mechanism that ensures a complete compression cycle.
   2. Double-bolted NEMA 2-hole terminals shall be used at locations where rotation of a single bolted terminal would result in contact or unacceptable clearance with other conductors or the enclosure and for terminations of conductors No. 2 AWG and larger.
   3. Acceptable Manufacturers.
      a. AMP, Thomas & Betts, Burndy or approved equal

B. Taps and Splices.
   1. Provide splices rated 5 kV and suitable for installation on unshielded 2.4kV or 5kV cable, comprised of splice connector, heavy-duty splice insulator/jacket, and environmental sealant.
      b. Splice insulator/jacket: wraparound, factory-expanded EPDM sleeve applied over rubber mastic tape making the completed assembly completely waterproof.
      c. Splices shall be watertight in locations with presence of moisture.
   2. Where splices are detailed on the Contract Drawings, install splice as shown and as directed by Sound Transit.
      a. In manholes and pull boxes, the splices shall be submersible.
   3. Acceptable Manufacturer.
      a. Burndy Copper Compression Connector, Type YS, or approved equal.
      b. 3M 5-8kV Cold Shrink Rubber splicing Kit, 5740-series, or approved equal.

2.05 OTHER MEDIUM-VOLTAGE CABLE CONNECTORS, TERMINATIONS, AND SPLICES

A. General.
   1. Medium-voltage terminations and splices shall be appropriate for the power cable specified in this Section.
2. Voltage rating shall be equal to or greater than the system full phase-to-phase voltage.

3. Provide appropriate compression connectors or terminals for use with stress cones and splices.

B. Stress Cone Terminations.

1. Molded construction for use with NEMA bolt-hole pattern lug terminals. Use lug terminals with at least two bolt holes.

2. Cold-shrink or hot-shrink termination kits appropriate for the size and configuration of medium-voltage cable being terminated.

3. Acceptable Manufacturer.
   a. Elastimold, 3M, Tyco/Raychem or approved equal

C. Splices

1. Pre-engineered cold-shrink splice kit with silicone rubber splice bodies for shielded solid dielectric cables meeting the requirements of IEEE 404. Splice kit shall provide primary cable insulation, shielding and grounding systems and durable, waterproof outer jacket equivalent to that of the original cable. Completed splice shall be rated for continuous operation at 105 degrees C. with an emergency overload temperature rating of 140 degrees C.

2. Splices for armored cables shall provide a means of reinstating the effectiveness of ground path of the armor and grounding conductors over the span of the installed splices.

3. Approved Manufacturers and Products:
   a. 3M QS-III or QS-IV
   b. Prysmian; or approved equal

2.06 TEST INSTRUMENTS

A. Electrical Megohmmeter for Insulation Testing.

1. 1000 Vdc output voltage suitable for resistance measurement from 500 kilohm to 500,000 megohms. Use a megohmmeter with an internal bleeder resistor for discharge.

2.07 SOURCE QUALITY CONTROL

A. Factory Design Tests.

1. Single-conductor unshielded cable
   a. Flame Test: Insulating material shall meet the IEEE 1202 exposure requirements for cable char height and total smoke released and peak smoke release rate of UL 1685.

2. Single-conductor shielded cable
a. Flame Test: Insulating material shall meet the IEEE 1202 exposure requirements for cable char height and total smoke released and peak smoke release rate of UL 1685.

b. Accelerated Aging Test: Cable insulation/shield system shall pass an Accelerated Aging Test performed in accordance with IEEE 1407, at four times rated line-to-ground voltage and without sample failure for a period of at least 1100 days.

PART 3 - EXECUTION

3.01 INSTALLATION

A. For general installation and installation submittal requirements see Section 26 05 00, Common Work Results for Systems Conductors and Cable.

3.02 MEDIUM-VOLTAGE CABLE TERMINATIONS AND SPLICES

A. Terminations and splices shall be made in a clean, dry, and warm environment. Vaults and boxes shall be cleaned, dried and warmed to a temperature recommended by the splice or termination manufacturer.

B. Install terminations, splices, connectors, connecting lugs, and tap plugs in accordance with the cable, terminator, and splice manufacturers’ instructions.

C. Torque bolted connections with a torque wrench to the values specified by manufacturer.

D. Connect medium-voltage cable supplied under this Contract to the equipment at its source and load ends. Connect appropriate, existing, properly terminated cables supplied under other contracts to the equipment provided under this Contract.

E. Locations of medium-voltage splices shall be shown and stationed on as-built drawings and identified prominently and permanently on tunnel walls.

3.03 MEDIUM-VOLTAGE CABLE GROUNDING

A. Ground each of the shielded medium-voltage cable segments throughout the length of the feeder as follows:

1. At the source and load ends, solidly ground the cable sheath, the cable grounding conductor, and conductor shields to the grounding electrode system.
2. Establish and maintain continuity of the raceways, the cable sheath, conductor shields, and cable grounding conductor throughout the feeder system.

3. Bonding and grounding connections shall be made using bolted or compression connectors.

3.04 FIELD ENGINEERING SERVICES

A. Provide the services of the cable manufacturer’s qualified Field Service Engineer.

B. Upon approval by Resident Engineer, Field Service Engineer shall have complete authority to represent and to act for the cable manufacturer.

C. Field service visits by this representative shall be before and during cable installation when requested by Resident Engineer and as required to fulfill the needs of Contractor.

D. Manufacturer’s technical representative shall be committed to this project in support of Contractor’s Work for the following:

   1. Cable installation in shafts: 120 hours
   2. Initial instruction in splicing and terminating: 16 hours
   3. Refresher instruction in splicing and terminating: 8 hours

E. The duties, responsibilities, and qualifications of the cable manufacturer’s technical representative shall be as follows:

   1. Instruction of Contractor’s installation personnel in proper splicing and termination procedures for this cable:
      a. One class shall be held prior to the make-up of permanent splices or terminations.
      b. A refresher class on the same subject shall be held midway through the cable installation work.
   2. Advising Contractor’s cable installation personnel on the proper procedures for the installation of the cable, including, but not limited to, lubricating and pulling the cable through raceways, installation in cable troughs and trays, making splices and terminations, and testing the cable.
   3. Have a thorough knowledge of the type of cable and its proper installation, support, and splicing and termination procedures in vertical and horizontal cable runs.
   4. Have a thorough knowledge of the proper cable testing procedures and acceptable test results.
   5. Have at least 10 years of experience in the installation of this type of power cable.

3.05 FIELD QUALITY CONTROL

A. Perform wire and cable tests in accordance with NETA ATS, IEEE 400 and IEEE 400.2:

   1. Testing organization shall be NETA certified with ten years of documented experience in testing of medium-voltage power cables as required below.
   2. Testing and safety procedures shall conform to recommendations of IEEE 400, cable manufacturer, test equipment manufacturer and testing organization.
B. Continuity Tests.
   1. Check continuity from point to point and check for shorts to ground with an ohmmeter.
   2. Perform tests after splicing is complete.

C. Wire and Cable Insulation Resistance Tests.
   1. Measure insulation resistance with a 1000 Vdc megohmmeter. Insulation resistance measurement may be made with the VLF test set if equipment is suitable for that purpose.
   2. Measure insulation resistance between conductor and ground.
   3. Test cables after splices and terminations are complete but before cable is terminated on equipment.

D. Cable Insulation Tests.
   1. Test cables with very low frequency (VLF) test equipment. For 26kV, 12 kV system cables, U₀ or line-to-ground voltage shall be considered to be 20kV, 6.9 kV respectively.
   2. Test in accordance with the recommendations of IEEE 400.2 at 0.1 Hz. The following tests shall be performed in the order given.
      a. Dissipation factor (‘tan-delta’ or loss angle) measurements shall be taken at 10-second intervals over a period of 60 seconds at 0.5U₀ (10kV, 3.45 kV) steps from 0.5 U₀ (10kV, 3.45 kV) to 2.0 U₀ (40kV, 13.8 kV).
      b. Voltage withstand test shall be run for a period of 60 minutes at the voltage recommended by IEEE 400.2 for 35kV, 12 kV cable.
   3. Include the following in the final field test report:
      a. Calculated tan-delta stability at U₀
      b. Calculated differential tan-delta (delta-tan-delta or tip up) between 0.5 U₀ to 1.5 U₀
      c. Mean tan-delta reading at U₀
      d. Results of VLF voltage withstand test

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes requirements for the following computer-based studies and reports for AC and DC switchgear associated with traction substations:

1. Short-circuit study.
2. AC coordination study.
3. DC coordination study.
4. Arc-flash hazard analysis study.

1.02 REFERENCES

A. Section incorporates by reference the latest revisions of the following documents, or if standard is adopted by the Authority Having Jurisdiction (AHJ), the latest revision adopted.

1. American National Standards Institute (ANSI):
   a. ANSI Z535.4 - Product Safety Signs and Labels.

2. Institute of Electrical and Electronics Engineers (IEEE):
   b. IEEE 242 - Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems.
   c. IEEE 399 - Recommended Practice for Industrial and Commercial Power Systems Analysis.
   d. IEEE 1015 - Recommended Practice for Applying Low-Voltage Circuit Breakers Used in Industrial and Commercial Power Systems.
   f. IEEE C37.20.1 - Standard for Metal-Enclosed Low-Voltage (1000 Vac and below, 3200 Vdc and below) Power Circuit Breaker Switchgear.
   h. IEEE C57.96 - Guide for Loading Dry-Type Distribution and Power Transformers.
3. Insulated Cable Engineers Association (ICEA):
   a. ICEA P-32-382 - Short Circuit Characteristics of Insulated Cables.
   b. ICEA P-45-482 - Short-Circuit Performance of Metallic Shields and Sheaths on Insulated Cable.

4. National Electrical Manufacturer’s Association (NEMA):
   a. NEMA MG 1 - Motors and Generators.

5. National Fire Protection Association (NFPA):
   a. NFPA 70 - National Electrical Code (with amendments by the Authority Having Jurisdiction).
   b. NFPA 70E - Standard for Electrical Safety in the Workplace.

1.03 SUBMITTALS

A. Product Data: Computer software to be used for system simulation.

B. Product Certificates:
   1. For short-circuit and overcurrent protective device coordination study, submit certification of compliance with IEEE 399.
   2. For arc-flash hazard analysis, submit certification of compliance with IEEE 1584.

C. Qualifications: Submit names, contact information and qualifications including references for at least five short-circuit, coordination study and arc-flash calculations of comparable complexity within the last five years.

D. Provide the following reports for each substation:
   1. Input data including completed computer program input data sheets.
   2. Short-Circuit Study and Equipment Evaluation Reports.
   3. AC Coordination Study Report: Submit at the same time as DC Coordination Study Report.
   4. DC Coordination Study Report.

1.04 QUALITY ASSURANCE

A. Studies shall use computer programs that are distributed nationally and are in wide use.
   1. Software algorithms shall comply with requirements of standards and guides specified in this Section.
   2. Manual calculations or calculations using spreadsheet software are not acceptable.

B. Study Specialist Qualifications:
1. Analysis and reports shall be prepared by an individual experienced in the application of computer simulations to traction power systems.

2. Qualifications shall be submitted for approval and shall document that the individual has at least five years’ experience and has prepared five studies of comparable complexity.

3. Analysis and reports shall be supervised and signed by a professional electrical engineer licensed in the State of Washington.

C. Studies, analysis, and reporting shall comply with the following standards:


2. IEEE 399 for general study procedures.

3. IEEE 1584 and NFPA 70E for arc-flash hazard analysis.

4. NFPA 70 (with AHJ amendments).

PART 2 - PRODUCTS

2.01 SIMULATION SOFTWARE

A. Acceptable Software: Subject to approval, simulation software shall be the product of one of the following developers:

1. CYME International.

2. Power Analytics Corporation.

3. Easy Power.

4. Operation Technology, Inc. / ETAP.

5. SKM Systems Analysis Inc.

2.02 SOFTWARE REQUIREMENTS

A. Computer software for short-circuit study shall include analytical features described in IEEE 399 as Mandatory, Very Desirable, and Desirable.

B. Computer software:

1. Shall be capable of plotting and diagramming time-current characteristic curves as part of the output.

2. Shall report device settings and ratings of all overcurrent protective devices.

3. Shall demonstrate selective coordination by computer-generated, time-current coordination plots using different colors for each protective device.

4. DC analysis results and settings shall be converted and integrated into the software-generated coordination plots if DC analysis is done separately and manually.
PART 3 - EXECUTION

3.01 DATA COLLECTION AND COORDINATION

A. Collect data from equipment suppliers, other contractors or subcontractors, power utility, and Sound Transit in order to complete the analysis.

B. Coordinate required distribution equipment ratings and protective device settings to provide a fully-integrated distribution system that is properly coordinated and meets the requirements of NFPA 70 (with Washington amendments).

C. Proceed with final analysis only after relevant equipment has been finally determined and submittal information is sufficient to produce accurate simulation results.

D. AC Systems Study requires the characteristics and loads of both AC loads and DC traction power loads.

3.02 SYSTEM DOCUMENTATION

A. Collect and tabulate the following input data to support studies:

1. Product data for overcurrent protective devices including devices furnished by others and involved in overcurrent protection.

2. Resistance and reactance data and fault current data from serving utility.

3. Electrical Distribution System Diagram. Provide documentation in both paper and electronic formats for the following:
   a. Circuit breaker and fuse current ratings and types.
   b. Relays and associated power and current transformer ratings and ratios.
   c. Transformer ratings including kVA ratings for each cooling type, primary and secondary voltages, connection type, transformer impedance, and X/R ratios. Provide information on transformer over-temperature sensors provided.
   d. Cable information including number in parallel, conductor material, compaction, sizes, insulation type and temperature ratings, and cable length.
   e. Busway material, ampacity, and impedance.
   f. Motor horsepower, full-load current and code letter according to NEMA MG 1.

4. Equipment data sheets:
   a. Special load considerations including starting inrush currents and frequent starting.
   b. Transformer characteristics, including primary protective device recommendations, inrush current, and thermal damage curve.
   c. Motor full-load current, locked-rotor current, service factor, starting time, type of starter, and thermal damage curve.
d. Utility protective device types, ratings and relay settings.

e. Special overcurrent protective device settings or types if required by the serving utility.

f. Time-current characteristic curves of devices to be coordinated.

g. Circuit breaker manufacturer, frame size, interrupting capacity, ampere or current sensor rating, long-time adjustment range, short-time adjustment range, and instantaneous adjustment range.

h. Overcurrent relay manufacturer, type, ampere tap range, time-delay range, instantaneous range, and current transformerratio.

i. Panelboard and switchboard, ampere rating and interrupting rating.

B. Use equipment identification tags that are consistent with electrical distribution system diagrams, overcurrent protective device submittals, input and output data, and recommended device settings.

3.03 SHORT-CIRCUIT STUDY

A. Calculate maximum available fault current in amperes rms symmetrical at overcurrent protective device positions throughout the electrical distribution system. Calculation shall be for current immediately after initiation of a three-phase bolted fault at each of the following:

1. Switchgear and switchboard bus.
2. Distribution panelboard.

B. Analyze the electrical distribution system from normal and alternate power sources throughout electrical distribution system. Include studies of system switching configurations and alternate operations that could result in maximum fault condition.

C. Calculate momentary and interrupting duties on the basis of maximum available fault current.

D. Calculations to verify interrupting ratings of overcurrent protective devices shall comply with IEEE 241 and IEEE 242.

1. For transformer, comply with IEEE C57.96.
2. For low-voltage circuit breakers, comply with IEEE 1015 and IEEE C37.20.1.
3. For low-voltage fuses, comply with IEEE C37.46.

E. Final Report:

1. Indicate calculated X/R ratios and equipment (half-cycle) fault currents on electrical one-line diagram.

F. Equipment Evaluation Report:

1. 600V overcurrent protective devices: Ensure that interrupting ratings are equal to or higher than calculated available half-cycle symmetrical fault current.
2. Devices and equipment rated for asymmetrical fault current: Apply multipliers listed in the Standards to half-cycle symmetrical fault current.

3. Conductors:
   a. Verify adequacy of phase conductors at maximum three-phase bolted fault currents.
   b. Verify adequacy of equipment grounding conductors and grounding electrode conductors at maximum ground-fault currents.
   c. Ensure that short-circuit withstand ratings are equal to or higher than calculated half-cycle symmetrical fault currents.

3.04 AC COORDINATION STUDY

A. Perform coordination study using approved computer software. Prepare a written report using results of short-circuit study. Comply with IEEE 399:
   1. Calculate the maximum and minimum half-cycle short-circuit currents.
   2. Calculate the maximum and minimum ground-fault currents.

B. Comply with IEEE 241 and IEEE 242 recommendations for fault currents and time intervals.

C. Transformer Primary Overcurrent Protective Devices:
   1. Devices shall not operate in response to the following:
      a. Transformer magnetizing inrush currents.
      b. Self-cooled, full-load current or forced-air-cooled, full-load current, as appropriate. For transformer equipped for future fan cooling option, overcurrent protective devices shall be capable of resetting to the higher forced-air-cooled rating.
      c. Permissible transformer overloads according to IEEE C57.96 if required by expected loading or emergency conditions.

D. Conductor Protection:
   1. Protect cables against damage from fault currents according to ICEA P-32-382, ICEA P-45-482, and conductor melting curves in IEEE 242.
   2. Demonstrate that equipment withstands the maximum short-circuit current for a time equivalent to the tripping time of the primary protection or total clearing time of the fuse.
   3. To determine temperatures that damage insulation, use curves from cable manufacturers or from listed standards indicating conductor size and short-circuit current.

E. Coordination Study Report: Prepare a written report including the following:
   1. A table with settings selected for overcurrent protective devices including:
b. Current transformer ratios and relay curve, tap, time-dial and instantaneous pickup settings.

c. Circuit breaker sensor rating and long-time, short-time and instantaneous trip settings.

d. Fuse type and current rating.

e. Ground-fault relay pickup and time-delay settings.

2. Coordination Curves:

a. Provide documentation of settings of overcurrent protective devices to achieve selective coordination.

b. Provide time-current curves to graphically illustrate that adequate time separation exists between devices installed in series, including utility upstream devices.

c. Prepare separate sets of curves for the switching schemes and for emergency periods where the power is fed from an alternate source.

d. Include the following information:
   1) Device identification tag.
   2) Time and current multipliers for curves.
   3) Three-phase and line-to-ground damage points for each transformer.
   4) No damage, melting, and clearing curves for fuses.
   5) Cable damage curves.
   6) Transformer inrush points.
   7) Maximum fault-current cutoff point.

3. Prepare and include in study completed data sheets for setting of overcurrent protective devices.

4. Graphs shall be plotted in both distinctive colors and line styles for each time-current characteristic and damage curve so that black-and-white copies of graphs are still understandable.

5. Provide both bound color copies and color electronic files in PDF format for report.

3.05 DC COORDINATION STUDY

A. Include the following as a minimum:

1. DC bolted positive to negative and positive to ground fault calculations.

2. Protective device range and setting calculations showing basis for each recommended relay setting.
3. Plots of rectifier design capability with actual margin of coordination (from breaker trip to design capability) clearly indicated at each of 100, 150, 300, and 450 percent full-load current and short-circuit current.

3.06 ARC-FLASH HAZARD ANALYSIS

A. Perform Arc-Flash Hazard Analysis with the aid of computer software intended for this purpose.

B. Perform analysis in conjunction with short-circuit and coordination studies.

C. Submit the results of the analysis in a table and include device or bus identification tag, bolted fault and arcing fault current levels, flash protection boundary, distances, personal-protective equipment classes and arc-flash incident energy (AFIE) levels.

D. Perform the analysis under worst-case fault conditions, and describe in the final report when applicable, how these conditions differ from worst-case bolted fault conditions.

E. Provide and install self-adhesive equipment labels in compliance with ANSI Z535.4 to document arc flash hazard and required personal protective equipment.

END OF SECTION
PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the establishment and maintenance of a TPSS System Reliability Program, which shall be applied to obtain a valid assessment of the MTBF capabilities of the designated equipment and subsystems furnished under this Contract. This program shall include:

1. The furnishing of predicted design reliabilities.
2. Field reliability testing.
3. Continual comparisons of field reliability testing.
4. All corrective measures required to obtain satisfactory performance.

B. The equipment and subsystems to be tested for system reliability compliance shall consist of:

1. LCMS PLC
2. LCMS HMI
3. IED PLC
4. IED HMI
5. DC Circuit Breaker
6. AC Circuit Breaker
7. Battery and Battery Charger

C. The Contractor will be permitted to submit reliability data previously acquired from similar equipment and subsystems for predicted reliabilities. If equipment selected is identical to equipment used within the existing Sound Transit operating system, the requirements herein can be waived upon written acceptance from the Resident Engineer. The contractor shall submit this request in writing with the specifics of the equipment and where used on the existing Sound Transit system.

D. Field reliability testing shall be on a subsystem basis with the subsystem as defined above. The Contractor shall initiate the field reliability testing at Substantial Completion. The testing duration shall be one year. If Chargeable Failures have accumulated to the extent that the requirements for MTBF for the sub-system cannot be met, the demonstration period shall be extended in order to obtain the cycles/mean time between failure thresholds specified herein. In the event demonstration period extends beyond Acceptance the Sound Transit designated personnel shall maintain equipment and collect field reliability data. The Contractor shall coordinate data collection with Sound Transit personnel.

1.02 SUBMITTALS
A. Reliability Program.

1. Within 180 days after award of the Contract, submit for review and approval the proposed reliability program plan. The program shall include, but not be limited to:
   a.) Organization and responsibilities of the proposed reliability effort.
   b.) Details of the Design and component selection and screening processes proposed to be used to meet the reliability requirements.
   c.) Details of the procedures proposed to be used to calculate MTBF predictions.
   d.) Identification of the sources proposed to be used for component reliability data.
   e.) Proposed serialized type forms and reports, including preventive maintenance and discrepancy reports specifically for the joint use of the Contractor and Sound Transit during the field reliability assessment-testing program.

B. Predicted Reliability Reports.

1. The Contractor shall submit the predicted reliability study 60 days prior to component procurement. The report shall provide the predicted reliability for each of the included subsystems and propose an alternate design or equipment for the approval of Sound Transit, if areas of common failure appear inherent in the specified design mode or equipment.

2. Update the reliability report and re-issue each 180 days until design of the designated subsystems is complete. Indicate for each subsystem the estimated percent of design completion upon which the reliability prediction is made.

3. Include in the report, an analysis of items for which the prediction does not meet the reliability requirements or for which the prediction had changed significantly from the last report. Describe the corrective action proposed in this Section of the report for items predicted not to meet the reliability requirements.

4. Provide an updated report to Sound Transit whenever deviations of the predicted reliabilities are encountered during design (i.e., prior to production). If these reports indicate a marked decrease in predicted reliability, Sound Transit may require an alternate design or equipment change to increase predicted reliability to the requirements specified in the Table of Reliability Goals.

C. Reliability Testing Procedures.

1. Obtain from Sound Transit approval of detailed test procedures before field reliability assessment testing begins. The test procedures shall include, but not be limited to, the following details:
   a.) A listing of components by description, part number, and quantity comprising each line item in the Table of Reliability Goals.
   b.) Graphical sample presentation of the test plan and table to be used.
   c.) Burn-in (debugging) time.
d.) Performance parameters to be measured.

e.) Performance limits beyond which a failure has occurred.

f.) Sample report and log forms to be used.

1.03 DEFINITIONS

A. The following definitions apply specifically to terms used in this Section.

1. Mean Time Between Failure (MTBF): The average time that the equipment will operate without a chargeable failure:

\[
\text{MTBF} = \frac{\text{operating time}}{\text{number of chargeable failures}}
\]

2. Minimum MTBF (MMTBF)

The value specified in the Table of Reliability Requirements by Sound Transit for minimum performance without rejection.

3. Chargeable Failure:

All failures which require repair or replacement of contractor provided components or parts are chargeable unless specified otherwise herein, or unless determined by Sound Transit to be caused by a condition external to the equipment under test. Failure due to workmanship deficiencies shall be counted as chargeable. Transient failures when proven to be caused by a single condition shall be counted only as a single failure. Also, transient conditions which temporarily prevent a function from being successfully performed shall be counted as chargeable failures unless it is shown that they are the result of external influences beyond the requirements of this Specification. Non-Chargeable Failures.

Failures which are proven to be the result of conditions exceeding those specified, (i.e., floods, derailments, vandalism, human error not normally protected against, etc.) shall be classed as non-chargeable and shall not be included in the reliability evaluation. Failure of parts installed or provided by others, such as network switches, that cause a dependent failure of a subsystem installed by the Contractor shall not be included in the reliability evaluation.

4. Failure Rate.

The reciprocal of MTBF. For this reliability assessment program, the failure rate is assumed to be constant throughout the life of the equipment.

5. Independent Failure.

A failure which will independently cause equipment performance outside of specified limits - one which occurs without being related to the failure of the associated items.

6. Dependent Failure.

A failure of a part which is a direct result of an independent failure - one which is caused by the failure of an associated item(s). Dependent failures are non-chargeable failures.

7. Simultaneous Failure: In the event simultaneous or multiple failures occur, each failed part which will independently prevent satisfactory equipment performance shall be counted as an equipment failure.
1.04 CONSTRUCTION OF TABLE OF RELIABILITY GOALS:

The Table of Reliability Goals is constructed of line items which represent identified subsystems. The specified table as constructed is shown at the end of this Section.

1.05 MATERIALS INVOLVED IN RELIABILITY PROGRAM

A. The equipment considered part of each line item shall be as follows:

1. Local Control and Monitoring System (LCMS).
   a.) All equipment, wire, terminals, etc. starting at the input and ending at the function outputs. Major components including: signal processor with I/O, plug connectors, component PC cards and connectors, capacitors, resistors, fuses, diodes, pushbuttons, switches, and data switching devices between processors.

2. LCMS HMI
   a.) All equipment, wire, terminals, etc. of the display and human interface portion of the LCMS.

3. Intelligent Electronic Device (IED).
   a.) All equipment, wire, terminals, etc. starting at the point of input and ending at the function outputs. Major components including: signal processor with I/O, plug connectors, component PC cards and connectors, capacitors, resistors, fuses, diodes, pushbuttons, switches, and data switching devices between processors.

4. IED HMI.
   a.) All equipment, wire, terminals, etc. of the display and human interface portion of the IED.

5. DC Circuit Breakers
   a.) All equipment, wire, terminals, etc. of the DC Circuit Breakers.

6. AC Circuit Breakers
   a.) All equipment, wire, terminals, etc. of the AC Circuit Breakers.

7. Battery and Battery Charger
   a.) All equipment, wire, terminals, etc. of the battery and battery charge equipment.

PART 2 - PRODUCTS

The product of this Section consists of the documents that establish and verify the reliability goals have been met as specified.

PART 3 - EXECUTION

3.01 ASSESSMENT PROGRAM
A. Verification that the equipment fulfills the reliability requirements described herein shall be per the approved reliability plan and as prescribed herein.

3.02 FIELD RELIABILITY DEMONSTRATION TESTING

A. The minimum reliability requirements for the various equipment types and sub-systems are specified in the Table of Reliability Goals.

B. Test all designated equipment and subsystems.

C. Modify or replace any subsystem or component part rejected by the reliability assessment program without additional cost to Sound Transit. Any such modification or replacement shall be subject to the approval of Sound Transit and subjected to the same reliability assessment program as the original equipment.

D. Reliability tests shall start and end as described within this specification. Data collection shall be per device; per subsystem; for each location with MTBF results cumulative of all like devices.

3.03 TEST PREPARATIONS

A. The Contractor's personnel assigned to participate in field data collection for reliability testing shall be fully trained in their assigned tasks and be familiar with the approved reliability test plan. It is expected that these shall be the Contractor personnel assigned to maintain the System until Final Acceptance.

B. The Contractor personnel assigned to evaluate reliability data, and supervise the overall execution of the reliability plan shall have performed a similar function for at least one prior major transit signals project.

3.04 ASSESSMENT REPORTS

Submit reliability assessment report every three months showing comparison of field reliability testing results with accept-reject criteria for each line item in the Table of Reliability Goals.

3.05 FINAL DOCUMENTATION

Submit a final reliability assessment report upon completion of specified reliability testing.

3.06 FAILURE DOCUMENTATION

A. Provide a report of any malfunction or fault which prevents or limits equipment from performing its function in accordance with these requirements. The report shall include:

1. Failure Rate.

2. Independent Failure.

3. Dependent Failure.

4. Simultaneous Failure.

5. Chargeable Failure

6. Non-chargeable Failure
3.07 PROCEDURE

A. Test Logs.

1. The logs shall contain the following information:
   
   a.) Identification of the component and subsystem by location, function, serial numbers (if applicable), and line item of Table of Reliability Goals to which the equipment is charged.
   
   b.) Number of like components and subsystems in service.
   
   c.) Date and time equipment was placed in service.
   
   d.) Date and time of each failure.
   
   e.) Cause of each failure.
   
   f.) Classification of each failure (chargeable, not chargeable).
   
   g.) All repairs and adjustments made and reasons for same.

2. Once each month, review the logs and make the following entries:

   a.) Accumulated operating hours per line item.

   b.) Accumulated chargeable failures per line item.

B. Preventive Maintenance.

1. Preventive maintenance procedures specified in the approved operating and maintenance manuals for the equipment during normal operation shall be performed during the reliability testing period. Any additional preventative maintenance during the period of the Contractor’s maintenance responsibility shall be recorded and evaluated for their effect on the reliability test.

2. Other maintenance actions required on behalf of other equipment such as troubleshooting, inspection, or downtime investigations shall be termed as preventive maintenance and classed as non-chargeable failures when performed in connection with reliability assessment.

C. Equipment Failure Record.

Maintain a failure record for each line item. The record shall be designed to permit keeping of the entire test history of each line item on a single sheet so that behavior of the line items may be easily recognized. This record shall show all component failures for the line item.

D. Verifying Repair.

Following repair or corrective action and prior to resumption of reliability testing, it shall be permissible to operate a maximum one week burn-in test to verify the effectiveness of the repair. Failures and repair time during this period shall be recorded and reported but not used in determining compliance with MTBF requirements.

E. Corrective Action.
When any reliability test reaches a reject decision, the test will be discontinued for that line item. Immediately notify Sound Transit. Develop and propose a plan for correction of the deficiencies. Sound Transit will review such corrective action and may require handling as a design change or modification.

F. Failure Summary Record.

Maintain a failure summary record containing all the information needed to reach an accept/reject decision on the system under test. The summary shall include all component failures considered chargeable on all like equipment under test. The record shall present the current test status, including information on the total hours of test, failures, and MTBF of all units on test.

3.08 MTBF EVALUATION CRITERIA

Acceptance or rejection of equipment shall be on an individual function basis with the individual functions being the line items presented in the Table of Reliability Goals. Accept or reject decisions shall be based upon the procedures, formulae, and definitions specified herein. If test results fall short of the specified hours or cycles then the Contractor is required to propose a corrective action acceptable to Sound Transit that may include a redesign or selection of alternative equipment in the subsystem if necessary. An extension of the reliability demonstration test shall then restart to prove the corrective action was sufficient.

**TABLE OF RELIABILITY GOALS**

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>MTBF Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>LCMS PLC</td>
<td>100,000</td>
</tr>
<tr>
<td>2.</td>
<td>LCMS HMI</td>
<td>100,000</td>
</tr>
<tr>
<td>3.</td>
<td>IED PLC</td>
<td>100,000</td>
</tr>
<tr>
<td>4.</td>
<td>IED HMI</td>
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<tr>
<td>5.</td>
<td>DC Circuit Breaker</td>
<td>Note 1</td>
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<td>AC Circuit Breaker</td>
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<tr>
<td>7.</td>
<td>Battery and Battery Charger</td>
<td>100,000</td>
</tr>
</tbody>
</table>

Note 1: Use IEEE C37.14 endurance requirements

Note 2: Use IEEE C37.06 endurance requirements

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. The Traction Electrification Distribution System referred to hereafter as the Overhead Contact System (OCS) consists of equipment needed to provide that part of the electrical circuit between the terminations of the Traction Power Substation positive feeders at disconnect switches, and the contact wire interface with the light rail vehicle pantograph.

a. This section covers the general requirements of the OCS for the Project.

b. The work may require coordination with multiple Civil, Structural, and Track contractors.

c. The Contractor shall also coordinate with Sound Transit, other agencies, localities, and authorities having jurisdiction regarding the work.

d. Work under the Contract includes detailed OCS design, materials procurement, installation, removal, return, disposal, salvage, scrapping, testing and commissioning of OCS equipment in accordance with the Contract Documents.

e. The OCS Contract Drawings, Specifications, and Sound Transit Light Rail Design Criteria provide information regarding this project and criteria for the Contractor to develop their OCS Design Package to completion, and install and test the Contractor’s products. The Contractor shall provide necessary engineering to ensure that the installed OCS meets the requirements of these Specifications and referenced Documents and Drawings.

f. The Contractor shall prepare a Contractor’s OCS Design Package with detailed information required for the OCS installation. The Contractor shall perform engineering and prepare designs that shall detail the use of the Contractor’s products and construction methods to achieve the required OCS installation.

g. The equipment to be procured and installed shall include poles and pole grounding, pole I.D. signs and markers, head and down guys, cantilevers, tunnel attachments, head spans, cross spans, conductors, conductor rail, feeders, jumpers, terminations, conductor tensioning devices, sectioning equipment, disconnect switches, surge arresters, contact wire-crossing assemblies, electrification warning signage and other overhead contact system associated components as shown in the Contract Documents.

h. OCS conductors shall be energized at a nominal 1500 volts DC, and shall be double insulated. A minimum of two levels of electrical insulation
shall be provided between the contact wire and a line pole or other grounded structure.

2. This section covers requirements for the tie-in of the OCS associated with the Project interface to the existing Link Light Rail Line.
   
   a. Construction work shall interface with the termination of the existing Light Rail Line. The existing OCS equipment shall be available for on-going revenue train operations on a daily basis. Closure of existing mainline tracks shall be restricted to non-operating hours and periods specifically set for construction.
   
   b. Planning the staging of these portions of the work shall be fully coordinated with Sound Transit Operations prior to any OCS tie-in work. The Contractor shall coordinate with the civil work and trackwork contractors to ensure that the OCS powering the existing system will perform as specified. New installations shall be tested at the end of each phase of trackwork installation, and prior to any OCS wiring entering revenue service.

3. This section covers the general requirements of OCS installations requiring attachment to structures.
   
   a. Coordination with WSDOT is required prior to any OCS work on a WSDOT structure.
   
   b. Coordination with Special Inspectors is required at structures where the owner of the structure requires Special Inspection.
   
   c. At bridge structures crossing over and under the route, the Contractor shall make field measurements, then design, manufacture and install site-specific equipment.
   
   d. Locate rebar in structures prior to installing anchors.
   
   e. Observe safety requirements for working in tunnels, under bridges, on bridges, and at all other structures.
   
   f. Additional requirements for the attachment of OCS to structures shall be as stated in Section 34 23 25 Overhead Contact System Anchorage to Concrete.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section. Additional reference standard requirements are as stated elsewhere in the Contract Documents.

2. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   
   a. AREMA (Chapter 33 – Railway Electrification)
3. American Society of Mechanical Engineers (ASME)
5. Institute of Electrical and Electronics Engineers (IEEE)
6. National Electrical Contractors Association
7. National Electrical Manufacturers Association (NEMA)
9. Society for Protective Coatings (SSPC)
10. Washington State Department of Transportation (WSDOT)
11. International Electrical Testing Association (NETA)

1.03 SUBMITTALS

A. The following General OCS items shall be submitted. Other OCS submittal requirements shall be as stated elsewhere in the Contract Documents.

1. OCS detail design documentation verifying the methods and materials used in installation shall be submitted.
   
a. Calculations shall include but not be limited to the following items.
   
1) Structural calculations for cantilever assembly and other similar support structures. Include verification that support structures can safely carry proposed conductor pre-stress tension used during installation.
   
2) Cantilever framing methodology and calculations.
   
3) Hanger calculations including those for spans containing variances due to contact wire and track grade, additional equipment, or conditions.
   
4) Sample calculations to verify computer calculations.
   
5) Calculation of worst case torsional forces on strain or stick insulators.
   
6) Calculations verifying the adequacy of installation rigging, including temporary or staging supports.

2. Drawings bearing the seal of a Professional Engineer registered in the State of Washington and qualified by experience shall be submitted if any design changes are made to the following items. The Engineer sealing these drawings shall have personally supervised the preparation of the Contractor’s OCS Design Package.
   
a. Master Overlap Chart: Reference the single line diagram showing the entire route relative to track alignment and civil features and include the following information.
   
1) Labels for each tension length.
   
2) Labels for each wire run number.
   
3) Labels and locations for each termination type.
   
4) Labels and locations for each mid-point anchor.
5) Locations of over bridges, under bridges, grade crossings, and stations.

b. OCS Layout Plan & Schedule Drawings: Include the following information.

1) Stationing of poles, portals, and tunnel supports.
2) Structure reference numbers for poles, portals, and tunnel supports.
3) Assembly allocations of poles, portals, and tunnel supports.
4) Stagger.
5) Contact wire height.
6) Messenger wire height.
7) Termination height.
8) Span length.
9) Structure offset for poles, portals, and tunnel supports.
10) Assembly allocations.
11) Section insulator types and locations.
12) Contact wire bridges.
13) Jumpers, feeders, pole mounted switches, and surge arresters.
14) Foundation schedule for at-grade poles.

c. Technical Sheets: Include the following information.

1) Design data.
2) Design parameters.
3) Conductor characteristics.
4) Clearance envelope.
5) Temperature conditions.
6) Conductor tensions.
7) Vertical, wind, and radial loads.
8) Hanger lengths.
9) Pantograph security.
10) Permissible mid span offset.
11) Maximum spans and staggers on tangent and curved track.
12) Vertical clearance from overhead conductors.
13) Wind blow off data.

d. General Arrangement Drawings: Show required relationship between multiple spans of wiring and multiple structures for the following configurations.

1) Typical tension length for tunnel, aerial structures, and open route.

2) Overlap types, including insulated overlaps, uninsulated overlaps, overlaps with feeders, and overlaps with disconnect switches.

3) Termination types.

4) Crossover types.

5) Midpoint types.

e. Typical Structures and Spans Drawings: Show typical spans and the relationships between various OCS assemblies needed for those span types, including the following.

1) Tunnel supports.

2) Center and side poles.

3) Feeder poles.

4) Poles with pole mounted disconnect switches.

5) Cross-span structures.

6) Standard, insulated overlap, and un-insulated overlap spans.

7) Crossover spans and structures.

8) Termination spans and structures.

9) Anchor structures including fixed terminated, mid-point, and balance weight anchors.

f. The Bill of Materials List (BOM) for each assembly and component in the Contract Drawings are representative only. As such, the Contractor's BOMs shall include the following.

1) Contractor number.

2) Supplier number.

3) Provision for Sound Transit's stores number.

4) Other data required for procurement of materials used in the construction of parts of the electrification system.

5) Cross-reference to related drawings and the BOMs.

6) Generic description or specification.

7) Brand name, where applicable.
8) Manufacturer's part number.
9) Original manufacturer or supplier, including address, telephone number, and contact person.
10) Notation on parts that are custom manufactured only upon request.

1.04 QUALITY ASSURANCE

A. Work specified in this Section shall be performed by Washington State unlimited licensed electricians working for an Electrical Contractor licensed by the State of Washington, skilled and experienced in the installation of the particular products specified in this Section, except as follows:

1. Welding shall be done by qualified, certified welders who make only those welds for which they have been qualified in accordance with AWS D1.1, ASME BPVC, Section IX, or other approved qualifying procedures.

2. Records of welder qualification tests shall be made available for review upon Resident Engineer’s request.

B. Post-installed anchors at existing concrete structures shall be installed by personnel meeting the requirements listed in Section 34 23 25 Overhead Contact System Anchorage to Concrete.

1.05 SUMMARY OCS DESIGN CRITERIA

A. All OCS design criteria and selected parameters shall comply with Sound Transit Light Rail Design Criteria as summarized in the following.

B. OCS configurations shall comply with the following.

1. Simple Catenary Auto Tensioned (SCAT) shall comply with the following.
   1) Open-Route Main Line Auto-Tensioned Simple Catenary.
      a) Install on the mainline track outside of tunnels in open route.
      b) The range of auto tensioning is from 5° F to 130° F.
      c) SCAT shall be single 350 kcmil contact wire, suspended from a 500 kcmil messenger wire by hangers.
      d) Conductors shall be tensioned with a balance weight and fixed termination at opposite ends of each tension length. Tension conductors according to charts provided in the Contract Drawings.
      e) SCAT shall maintain a normal system height of 4 feet unless dictated otherwise in the Contract Drawings.

2. Low Profile Simple Catenary Auto Tensioned LPSCAT shall comply with the following.
   1) Open-Route Main Line Low Profile Auto-Tensioned Simple Catenary.
      a) Install on the mainline track at low clearance overhead bridges in open route.
b. The range of auto tensioning is from 5° F to 130°F.

c. LPSCAT shall be single 350 kcmil contact wire, suspended from a 500 kcmil messenger wire by hangers.

d. Conductors shall be tensioned with a balance weight and fixed termination at opposite ends of each tension length. Tension conductors according to charts provided in the Contract Drawings.

e. LPSCAT shall have a normal system height of 1 foot 3 inches unless dictated otherwise in the Contract Drawings.

3. SWFT –Single Wire Fixed Terminated (variable tension):

a. Location: Install in Storage Yards and Operations and Maintenance Facilities.

b. Configuration: Single 350 kcmil contact wire.

c. Tensioning: Conductors shall be fixed terminated with variable tension. Tension conductors according to tensioning charts provided in Contract Drawings.

4. Low Profile Simple Catenary Fixed Terminated (LPSCFT, variable tension) shall comply with the following.

1) Low Profile Fixed-Terminated Simple Catenary.

a) LPSCFT shall be installed on the mainline track in tunnel sections and in low clearance areas as shown in the Contract Documents. At termination locations, if required, the messenger wire shall terminate to avoid overhead obstructions and the contact wire shall extend beyond the messenger wire termination.

b. LPSCFT shall be single 350 kcmil contact wire, suspended from a 500 kcmil messenger wire by hangers.

c. Conductors shall be fixed terminated with variable tension. Tension conductors according to tensioning charts provided in the Contract Drawings.

d. LPSCFT shall maintain a normal system height of 1 foot 3 inches unless dictated otherwise in the Contract Drawings.

5. Tunnel Conductor Rail (CR) and the corresponding requirements, shall be as stated elsewhere in the Contract Documents.

C. The ambient temperatures considered for design shall be as follows.

1. The range of temperatures in tunnels is listed below.

a. Maximum temperature is 100 degrees F.

b. Normal temperature is 60 degrees F.

c. Minimum temperature is 40 degrees F.

2. The range of temperatures in open route areas is listed below.
a. Maximum temperature is 107 degrees F.

b. Normal temperature is 60 degrees F.

c. Minimum temperature is 0 degrees F.

D. Ice loading conditions to be considered for design shall be as follows.
   1. In tunnels, ice loading is not required for consideration.
   2. In open route, the following ice loading shall be considered.
      a. Radial ice loading (operating with 40 mph wind) shall be ½ inch on MW, ¼ inch on CW.
      b. Radial ice loading (non-operating) shall be ½ inch on MW, ½ inch on CW.

E. The design wind loads shall be as follows.
   1. Wind loads in tunnels are listed below.
      a. Maximum wind speed for structural design shall be 55 mph.
      b. Maximum wind speed for train operations shall be 55 mph.
   2. Wind loads for open route areas are listed below.
      a. Maximum wind speed for structural design shall be 70 mph.
      b. Maximum wind speed for train operations shall be 55 mph.

F. Electrical clearance requirements shall be as follows.
   1. Minimum Static Clearance shall be 5 inches.
   2. Minimum Passing Clearance shall be 3 inches.
   3. Erected supports, brackets, cables, and other installed equipment shall comply with the LRV and pantograph clearance envelope as indicated in the Contract Drawings.

G. Contact Wire Heights, as referenced to top of high rail level of individual NB and SB tracks at a specified support location, shall be as follows.
   1. Exclusive Right-of-Way at grade or Elevated Trackway shall be a minimum of 15 feet.
   2. In-Street running shall be a minimum of 20 feet, 6 inches. Attachment heights may need increased to meet NESC minimum of 20 feet over roadway at worst case sag.
   3. Road and street grade crossings shall be a minimum of 20 feet, 6 inches. Attachment heights may need increased to meet NESC minimum of 20 feet over roadway at worst case sag.
   4. Railroad crossings shall be a minimum of 22 feet, 6 inches.
   5. New tunnels shall be 13 feet, 10 inches.
   6. Existing tunnels shall be 13 feet.
H. Factors of safety under operating and non-operating conditions for OCS design shall be as follows.

1. Conductors shall meet the factors of safety listed below.
   a. Minimum factor of safety under operating conditions shall be 2.0.
   b. Minimum factor of safety under non-operating conditions shall be 1.6.

2. Other wires, components, assemblies, and hardware shall meet the factors of safety listed below.
   a. Minimum factor of safety for slippage or breakage under operating conditions shall be 2.0.
   b. Minimum factor of safety for slippage or breakage under non-operating conditions shall be 1.6.

3. The permitted wear of the contact wire is 30 percent of its original cross sectional area. The safety factors stated above apply to the contact wire when worn.

I. Contact wire gradients and changes in contact wire gradient shall be as follows.

   1. The maximum constant gradient shall be 1 percent.
   2. The maximum change in gradient shall be 0.5 percent.

J. Pantograph security shall meet the following requirements.

   1. The minimum pantograph security shall be 6 inches
   2. The pantograph uplift allowance shall be as follows.
      a. In tunnels the uplift shall allow for 1-1/2 inches of mechanical passing clearance.
      b. In open route the uplift shall allow for 3 inches of mechanical passing clearance.
      c. The pantograph clearance envelope shall include an additional 4 inches electrical passing clearance to the pantograph head.

K. The permissible mid span offset shall be as follows.

   1. Maximum 12 inches or as dictated by the Technical Sheets.
   2. Installation tolerance shall be 1 inch.

L. Contact wire radial loads shall be as follows.

   1. Cantilever load requirements shall be as shown in the Contract Drawings.
   2. Pull off assemblies shall only be used for steady arm pull off loadings in excess of 200 pounds at any temperature or wind condition.
   3. Maximum contact wire deviation at a single contact wire swivel clamp shall be 7 degrees. At registrations requiring contact wire deviation angles greater than 7 degrees, a second contact swivel clamp shall be required.

M. The heel settings shall be as follows.
1. Calculate steady arm heel settings, the vertical distance from contact wire level to the swivel point of the steady arm, as a resultant of vertical and radial loads present at each registration point.

2. Minimum steady arm heel setting shall be 1 inch.

3. Install heel point of steady arm outside of the pantograph clearance envelope.

N. The pantograph clearance envelope requirements are as follows.

1. For pantograph envelope and related clearance requirements, see OCS Contract Drawings.

2. The installed OCS, including the steady arm in the uplifted position, shall not intrude into the pantograph mechanical clearance envelope for the applicable contact wire height, allowing for uplift of the contact wire described as described below.

3. The pantograph electrical clearance envelope to live OCS equipment shall be used where OCS fittings are insulated from ground by at least one level of system rated insulation and are not electrically connected to other OCS circuits. For other cases the pantograph clearance envelope for grounded structures and equipment shall be used.

4. For OCS test purposes, lift the pantograph 3 inches on open track and 1-1/2 inches in the tunnel from installed contact wire height to verify passing clearance of steady arms.

5. All OCS assemblies and structures shall meet the specified vehicle dynamic clearance envelope.

O. Tolerances requirements are as follows.

1. The change in span length due to a change in structure stationing may not result in exceeding the maximum span, as shown in the Contract Documents.

2. Tolerance requirements for OCS Installation are provided elsewhere in these Specifications.

P. The nominal OCS voltage shall be 1500 Vdc.

Q. Electrical Insulation requirements are as follows.

1. Rate each level of insulation to be compatible with the system insulation class.

2. At OCS supports, provide a minimum of 2 levels of electrical insulation between bare live conductors and a grounded structure.
   a. Provide first level of insulation at contact wire clamp and the messenger wire support clamp.
   b. Provide second level of insulation adjacent to the support structure.
   c. In headspan wires, cross span wires and span guys locate insulators in accordance with the requirements as shown in the Contract Drawings.
   d. Examine sectionalizing diagrams and assembly allocations for additional inter-track isolation requirements.
3. At contact wire and messenger wire anchor/terminating spans, provide 2 strain insulators separated by a minimum distance as indicated in the Contract Drawings.
   a. Locate one level of insulation in the anchor span approximately 5 feet from the projected superelevated center line of track, and one level between 3 feet and 5 feet from anchor attachments. All catenary support and termination assemblies, including head spans, cross spans and pull off assemblies, shall be double insulated.

4. At spans with backbones and pull-off bridles, locate strain insulators 5 feet from the poles and locate the second level at the contact wire clamp and in the messenger pull-off wire.

5. At pull-offs from poles locate one level adjacent to the pole and the second at the contact wire clamp. For two-track pull-offs locate additional insulation between tracks if required.

6. At OCS in open track areas the arrangement of primary and secondary insulation shall be installed such that a minimum of 4 feet 0 inches separates an energized component from a grounded component. This requirement shall not apply in tunnels nor conductor rail installations.

R. Headspans shall be designed with maximum sag approximately equal to length of head span divided by 8.

S. Aesthetics shall be considered when determining assemblies and components in passenger stations. Assemblies and components shall be low profile, and well blended to immediate surrounding structures in order to minimize the visual impact in passenger stations.

PART 2 - PRODUCTS

2.01 GENERAL PERFORMANCE

A. Regulatory requirements shall be as follows.
   1. Comply with current federal, state and local requirements.
   2. Comply with codes and regulations consistent with best industry practices of OCS fabrication and installation, including but not limited to, AISC, ASTM, AWS, IEEE, NEC, and NESC.
   3. Conform to the standards as stated elsewhere in the Contract Documents.

B. General performance requirements are as follows.
   1. Provide electrification equipment proven in similar railroad, rail transit, or heavy industrial service and make use of this experience to prepare a suitable and proven design for this application.
   2. Each component, subassembly and assembly provided in this Contract shall be of a proven design with a minimum history of 5 years successful operation at the time of Contract award in similar railroad or rail transit service applications.
   3. Integrate OCS elements, such that specified requirements are achieved without conflict or error within or between specified elements, and between the OCS and other Systems and Civil components.
4. Life cycle requirements are as follows.
   a. The Traction Electrification System expected service life shall be 30 years in continuous service, 24 hours a day, 365 days a year.
   b. Use off-the-shelf service-proven equipment and hardware to achieve this useful life.
   c. Provide replacement spare parts that are functionally and physically interchangeable for each product class.

2.02 MANUFACTURER QUALIFICATIONS

A. The manufacturers of the OCS materials, components, and assemblies shall meet the following qualifications.

1. Original equipment manufacturer (OEM) of OCS components shall be regularly engaged in the manufacture of such components.
2. OEM shall have at least 5 years of experience in successfully providing OCS products.
3. OEM shall certify that products are suitable for the application for which they are proposed for the work.

B. Welder Qualification requirements shall be as follows, and as stated elsewhere in the Contract Documents.

1. Welding shall be done by qualified, certified welders who make only those welds for which they have been qualified in accordance with AWS D1.1, ASME BPVC, Section IX, or other approved qualifying procedures.
2. Records of welder qualification tests shall be made available for review upon Resident Engineer’s request.

2.03 GENERAL MATERIAL AND EQUIPMENT REQUIREMENTS

A. Materials and Equipment requirements are as follows.

1. Material shall be new and free from damage or wear, suitable for the use intended and of the manufacturer’s latest standard design.
2. Materials and equipment provided shall meet the dimensions as shown on the Contract Drawings, or as required by site specific measurements.
3. Provided materials and equipment shall be standard products of manufacturers regularly engaged in the production of such material and equipment.
4. Where 2 or more units of the same class of material or equipment are required, provide products of a single manufacturer.
5. Similar component parts of different larger assemblies shall not be required to be the products of the same manufacturer.
6. Discontinued materials or products shall not be permitted.
7. Each type of material and equipment shall be of the same manufacturer and quality throughout the Work.

B. Listed and labeled equipment and material shall meet the following requirements.
1. Provide evidence of equipment labels and listed documentation for all materials, components, and assemblies.

2. Materials that are not listed or labeled require approval by the Resident Engineer prior to use.

3. Products which have not been tested or certified for the use intended shall not be used when equivalent listed or labeled materials are available.

4. The label or listing will be acceptable as sufficient evidence that the materials and equipment conform to the specified standards.

5. Electrical equipment and material not listed or labeled shall be furnished with a Field Evaluation label provided by a Testing Laboratory approved by the Washington State Department of Labor and Industries (L&I), and certifying that the equipment conforms to the requirements of UL and IEEE or ANSI.

6. This product evaluation may be performed in the factory or on-site as approved by L&I.

7. A request for permission to perform a Field Evaluation in the factory or onsite shall be submitted to L&I for approval.

C. Material and equipment shall be designed to ensure satisfactory operation and life in the environmental conditions that exist where the material or equipment is installed.

D. Dissimilar material connection requirements are as follows.

1. Not permitted at electrical connections or connections requiring disassembly for maintenance or for removal and replacement of equipment.

2. Not permitted except at permanent connections.

3. Provide suitable electrochemical isolation.

4. Isolation treatments shall be permanent and not require maintenance or replacement for the life of the equipment or installation.

2.04 FINISHES

A. Galvanizing requirements are as follows.

1. Wherever “galvanized” is called out, the material shall be “hot-dip galvanized” and coated in accordance with ASTM A123 or A153.

2. Wherever materials are called out as “hot-dip galvanized” or “galvanized”, the coating is intended to be applied in addition to normal manufacturer’s finish.

3. Materials or products specified which are not readily available in the specified hot-dip finish, shall be “custom” hot-dip galvanized after manufacture by an independent galvanizer.

4. Where finishes are called out as galvanized and the specified product cannot be either manufactured with a hot-dip finish, or cannot be hot-dip galvanized after manufacture, the specified product shall be furnished with a finish that will perform equal to hot-dip galvanizing, and as approved by the Resident Engineer.
2.05 PACKAGING, DELIVERY, STORAGE AND HANDLING

A. Deliver materials, components, assemblies, and equipment to job site in unbroken packages, reels, or other forms of containers. Package insulators to prevent damage during transport and installation.

B. Ship wire, wire rope, and cable on suitable reels. Each reel shall have a strong, weatherproof tag securely fastened to it giving physical and mechanical properties as well as material type designation, Standard designation, and name and mark of manufacturer.

PART 3 - EXECUTION

3.01 INSTALLER'S QUALIFICATIONS

A. General installation qualification requirements are as follows.

1. Installation personnel shall meet the following licensing and certification requirements.
   a. All work specified in this shall be performed by workers skilled and experienced in the installation of OCS systems.
   b. Field welding shall be performed by qualified, certified, welders who make only those welds for which they have been qualified in accordance with AWS D1.1. Records of welder qualification tests shall be made available for review upon request from Sound Transit.
   c. The requirements for personnel performing the installation of post-installed anchors at existing concrete structures shall be as stated in Section 34 23 25 Overhead Contact System Anchorage to Concrete.

2. OCS Installation Supervisor qualification requirements are as follows.
   a. An OCS Installation Supervisor shall be appointed to supervise the complete OCS installation, field testing, and commissioning of the OCS equipment provided under this Contract.
   b. The OCS Installation Supervisor shall have a minimum 10 years of experience as a superintendent or general foreman in charge of OCS installations.
   c. The OCS Installation Supervisor shall not be the same person designated to be the Traction Power Installation Supervisor.
   d. The OCS Installation Supervisor shall be trained and qualified for installation by the OCS equipment manufacturer.

3. OCS Installation Crew Foreman qualifications shall meet the following.
   a. A foreman shall be appointed for each crew not exceeding six OCS installers or where crews work independently.
   b. The foreman shall have a minimum 10 years of experience in the installation of OCS and demonstrated experience as foreman of OCS installations or similar overhead line work.

4. OCS Installer qualifications shall meet the following.
a. OCS Installers shall be qualified by experience and training to perform the specified work, and shall be outside linesmen who are employees of a Washington licensed electrical Contractor.

b. Journeyman Linemen shall have completed a State of Washington or federally approved Outside Line Construction and Maintenance apprenticeship program of 6000 hours of on-the-job training.

B. Personnel performing nondestructive testing shall meet the following requirements.

1. Personnel shall be certified by the American Society for Nondestructive Testing.

   a. Only personnel certified for NDT Level I and working under a NDT Level II person or persons certified for NDT Level II may perform nondestructive testing.

3.02 OCS INSTALLATION

A. Installation of the OCS shall be in accordance with the requirements of the specifications, contract documents, applicable national and local codes, and industry best practices.

B. Structure offsets, including poles and attachments, shall be measured from centerline of track to centerline of structure at track level. At locations where the centerline of the structure differs from the centerline of anchor bolts the structure offsets refer to the centerline of the anchor bolt group.

C. For all areas the outbound outside and center foundations reference the outbound track and the inbound outside foundations reference the inbound track, where the outbound track has increasing stationing and the inbound track has decreasing stationing.

D. Offsets and staggers for all tracks shall be oriented when viewing increasing station.

E. The contractor shall field verify the location, offset, elevation and foundation types including the anchor rod, ferrule, or insert pattern prior to final fabrication and installation of poles, support structures, guys and hardware.

F. All dimensions, details and elevations of existing items shall be field verified by the contractor prior to the fabrication of OCS structures and other associated fixtures or appurtenances.

G. Loadings indicated on assembly drawings are minimum requirements. The contractor shall determine the actual loading ranges for the hardware and assemblies being supplied. Alternative assemblies and configurations for the OCS are acceptable subject to approval by the Resident Engineer.

H. The Bills of Material for OCS assemblies as provided in the Contract Documents contain major components in a typical configuration. The contractor shall provide additional components as required to complete the assemblies, including site-specific modifications where necessary and approved by the authority.

I. The Contractor shall size the components in the OCS assemblies to meet the required loadings in conjunction with the configuration requirements of the OCS manufacturer’s components within the assembly.

J. Pole brackets have been optimized for back-to-back arrangements where practical. The contractor shall adjust the brackets as required dependent on the hardware and assemblies supplied, support configuration, pole type and size, and aesthetics.
K. Termination heights provided on the OCS layout plans are for initial installation only. The contractor shall adjust all termination heights as required to accommodate the hardware being furnished, final contact wire profile, track profile, and actual field dimensions.

L. The messenger wire shall be positioned directly above the contact wire at all times, with the exception of split termination spans.

M. The conductor heights in the OCS layout plans reference the mean top of rail level of the track projected along the superelevated centerline of the track at each support location.

N. The stagger in the OCS layout plans reference the superelevated centerline of the track normal to the plane between the rails of that track.

O. The system height of catenary is measured from the bottom of the contact wire to the centerline of the messenger wire at the support.

P. The contractor shall field verify each span between vertical support locations prior to determining the required number of hangers and their lengths.

Q. Hangers installed at any point of any span when the system height is less than 10 inches shall be "V" configuration.

R. Conductor rail stagger, support attachments, span lengths, and termination arrangements shall be reviewed and modified as required by the manufacturer and supplier of the conductor rail system components.

S. OCS poles shall be raked as necessary to ensure they are plumb when all static loads are applied. Contractor shall provide the rake values in the as-built drawings.

T. All structure offsets shall satisfy minimum clearance requirements for vehicles and pantographs, fully allowing for track curvature and the superelevation as designed at that location.

U. OCS installation shall comply with the requirements as stated elsewhere in the Contract Documents.

3.03 DEMOLITION, REMOVALS, RETURN, SALVAGE, AND SCRAP

A. Requirements for demolition, removal, return, salvage, and scrap of OCS materials and equipment shall be as stated elsewhere in the Contract Documents.

3.04 CAPITAL SPARE PARTS AND MAINTENANCE EQUIPMENT

A. Requirements for capital spare parts and maintenance equipment shall be as stated elsewhere in the Contract Documents.

3.05 SPECIAL MAINTENANCE TOOLS

A. Requirements for special maintenance tools shall be as stated elsewhere in the Contract Documents.

3.06 TESTING AND COMMISSIONING

A. Requirements for testing and commissioning shall be as stated elsewhere in the Contract Documents.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Work of this Section includes preparing surfaces, furnishing and applying abrasion resistant coating systems for the exterior exposed surfaces of galvanized steel OCS poles shown on the Contract Drawings or specified herein.

2. Field touch-up of damaged paint surfaces.

B. Work Not Included:

1. Unless otherwise indicated, painting is not required on surfaces of permanently concealed areas, pre-finished items, finished metal surfaces, operating parts and labels such as Underwriters Laboratories, Factory Mutual, or other code required labels or equipment name, identification, performance rating or nomenclature plates. Areas concealed by decorative bases and medallions shall not be considered as permanently concealed.

2. OCS pole bands, brackets, OCS cantilevers, insulators, OCS switches, brackets, operating handles, support wires, fittings, bare conductors, insulated conductors, anchor bolts, nuts, washers, or any other item that is not specifically part of the OCS pole or OCS structure assembly shall not be painted.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.


2. ASTM D3363 - Standard Test Method for Film Hardness by Pencil Test.


5. ASTM D6386 – Standard Practice for Preparation of Zinc (Hot-Dip Galvanized) Coated Iron and Steel Products and Hardware Surfaces for Painting.


1.03 ADMINISTRATIVE REQUIREMENTS

A. Coordination:

1. Review sections in which other coatings are provided to ensure compatibility of the total systems for various substrates. On request, furnish information on the characteristics of specified finish materials to ensure compatible primers.

2. Coordinate with the galvanizer to ensure that painting process is compatible with the galvanizing process.

3. Notify the Resident Engineer of problems anticipated using the coatings specified over substrates primed under other sections.

1.04 SUBMITTALS

A. Submit:

1. Product Data: For each paint system specified, including primers:
   a. Submit the manufacturer's technical information including label analysis and instructions for handling, storage and application of each material proposed for use.
   b. Submit a list of each material and cross-reference the specific coating, finish system and application. Identify each material by the manufacturer's catalog number and general classification.
   c. Submit material safety data sheets for all abrasion resistant coating primers, intermediate coats, finish coats, cleaning agents and thinners.

2. Product List: Identify products to be applied and state whether materials are to be applied in the shop or in the field.

3. Application Process: For each paint application process:
   a. Submit the applicator's processes for preparing the hot-dip galvanized surfaces, applying the primer coats, intermediate coats, and finish coats, using cleaning agents and thinners, and repairing defects.

4. Field Touch-Up Process:
   a. Submit processes for touching up damaged paint surfaces in the field.

5. Samples:
   a. Submit samples of each color and material to be applied with texture to simulate actual conditions on representative samples of the actual substrate.
   b. Submit stepped samples, defining each separate coat, including primers. Use representative colors when preparing samples for review. Resubmit until the required sheen, color and texture is achieved.
   c. Submit a list of material and application for each coat of each sample. Label each sample as to location and application.
   d. Submit six inch-square samples of each color and finish on each type of metal (galvanized-coated steel, aluminum-zinc-alloy-coated steel, bare steel, etc.) for Resident Engineer's review of color and texture.
6. Certificates: Submit certification by the manufacturer that the products supplied comply with Washington regulations controlling use of Volatile Organic Compounds (VOCs).

7. Qualifications Statements: Submit qualification data for manufacturers and applicators to demonstrate their capabilities and experience.

1.05 QUALITY ASSURANCE

A. Qualifications:

1. Applicator Qualifications: Engage an experienced applicator that has completed painting system applications similar in material and extent to those indicated for the Project and that have resulted in a construction record of successful in-service performance.

   a. Include a list of completed projects with project names, addresses, names of Engineers, Architects and Owners and associated phone numbers, plus other information specified where identical products have been applied.

B. Consult with the galvanizer and the paint manufacturer before applying a post-treatment to galvanized steel that is to be painted.

C. Single Source Responsibility: Provide primers and undercoat paint produced by the same manufacturer as the finish coats; in all cases where the Contractor has control of primers and undercoat paints applied to items to be finish painted. Paint materials not otherwise specified shall be products of one manufacturer regularly producing materials of types specified.

D. Materials shall be applied and reduced only as specified or recommended by the paint manufacturer's printed instructions. Where the manufacturer has made additional recommendations, apparently in conflict with these Specifications, allow the Resident Engineer to review the additional recommendations before proceeding.

E. Field Samples / Mock-Ups:

1. Request inspection by the Resident Engineer of the first finished item of each color scheme required as a field sample of selected colors, finish, texture and gloss under illumination equal to that expected at acceptance.

2. Acceptable field samples will be used to establish the Project standard.

1.06 DELIVERY, STORAGE AND HANDLING

A. Delivery and Acceptance Requirements: Deliver materials to the jobsite in the manufacturer's original, unopened packages and containers bearing the manufacturer's name and label and the following information:

1. The Product name or title of the material.

2. The Product description (generic classification or binder type) and the Manufacturer's name.

3. The Manufacturer's stock number and date of manufacture.

4. The contents by volume, of pigment and vehicle constituents.

5. Thinning instructions.
6. Application instructions.

7. Color name and number.

8. Handling Instructions and precautions.

B. Storage Requirements:

1. Store materials not in use in tightly covered containers in a well-ventilated area at a minimum ambient temperature of 45 degrees F and according to manufacturer’s written instructions. Protect from freezing. Maintain containers used in storage in a clean condition, free of foreign materials and residue.

2. Keep storage area neat and orderly. Remove oily and paint-soiled rags, contaminated paint and waste daily. Take necessary measures to ensure that the workers and Work areas are protected from fire and health hazards resulting from the handling, mixing and application.

3. The Contractor shall store all flammable paints and solvents in accordance with Federal, State, and Local requirements.

C. Handling Requirements:

1. All painted poles and structures shall be handled and stored by the Contractor to prevent damage to the paint and coatings.

2. Painted poles and structures shall be delivered to installation site in a finished condition. Any damage requiring field touch-up shall conform to these Specifications and the paint manufacturer’s written instructions.

1.07 FIELD/SITE CONDITIONS

A. Environmental Conditions:

1. Perform all painting processes at a facility that ensures environmental conditions will not adversely affect the quality of the final product.

2. Comply with paint manufacturer’s recommendations concerning environmental conditions under which the paint systems may be applied.

3. Apply coatings only when the temperature of the surfaces to be painted and the surrounding air temperatures are between 45 degrees F and 95 degrees F.

4. Do not apply coatings in the following circumstances:
   a. Snow, rain, fog, or mist.
   b. When the relative humidity exceeds 85 percent.
   c. At temperatures less than five degrees F above the dew point.
   d. To damp or wet surfaces.
   e. Where dust of foreign contaminants are blowing in the air.
   f. Against manufacturer’s recommendations for the application.

5. The Contractor shall ensure adequate ventilation during interior painting.
PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Manufacturer List: Subject to compliance with specification requirements, provide best quality products from the following:

2. Tnemec.
3. Or approved equal.

2.02 ABRASION RESISTANT COATING MATERIALS, GENERAL

A. Abrasion resistant coating system is a two-component, pigmented, aliphatic, polyurethane coating.

B. Material Compatibility: Provide primers, finish coat materials and related materials that are compatible with one another and the substrates indicated under conditions of service and application as demonstrated by the manufacturer based on testing and field experience. Factory applied primers shall be compatible with intermediate and finish coat materials.

C. Material Quality: Provide the highest grade of the various coatings as regularly manufactured by acceptable coating manufacturers. Materials not displaying manufacturer's identification as a best-grade product will not be acceptable.

D. Colors: Provide custom colors of the finish coat to match colors specified in the Contract Documents.

2.03 PRIMERS

A. Galvanized Steel:

1. Prepare surface per SSPC SP-1 Solvent Cleaning.
2. Provide the manufacturer's recommended factory-formulated primer that is compatible with the substrate and finish materials indicated.
3. Manufacturers/Products: Subject to compliance with requirements, products that may be incorporated in the Work include, but are not limited to:
   a. DTM Wash Primer B71Y1 by Sherwin Williams, 0.7 to 1.3 mils dry film thickness.
   b. Series N69 Hi-Build Epoxoline II by Tnemec, 4-6 mils dry film thickness.
   c. Or approved equal.

2.04 INTERMEDIATE COAT MATERIALS

A. Provide the manufacturer's recommended factory-formulated intermediate coat for galvanized steel. Verify that it is compatible with the substrate and primer and the finish materials indicated.

1. Manufacturers/Products: Subject to compliance with requirements, intermediate coat materials that may be incorporated in the Work include, but are not limited to:
2. Recoatable Epoxy Primer B67 Series by Sherwin-Williams, 4.0 mils minimum dry film thickness.

3. Series N69 Hi-Build Epoxoline II by Tnemec, 4-6 mils dry film thickness.

4. Or approved equal.

B. Touch-Up Primer: Provide the manufacturer’s recommended factory-formulated touch-up primer that is compatible with the substrate, primer, intermediate coat and the finish materials indicated as noted in this Section.

2.05 FINISH COAT MATERIALS

A. Provide one coat of manufacturer’s recommended factory-formulated Pigmented, Aliphatic, Polyurethane finish-coat materials that are compatible with the substrate and base coat materials.

1. Physical Properties of Topcoat.
   a. Abrasion Resistance; ASTM D4060, Taber CS-17 wheel, 1000 cycles, 1-kg weight: maximum 155-mg loss.
   b. Pencil Hardness; ASTM D3363: B.
   c. Salt Fog Resistance; ASTM B117, 1000 hours: "Excellent".
   d. Elcometer Adhesion; ASTM D4541, 700 psi (average of 3 pulls) minimum.
   e. Provide system recommended by manufacturer for future field repair by untrained applicators employed by the Owner.

B. Manufacturers/Products: Subject to compliance with requirements, finish coat materials that may be incorporated in the Work include, but are not limited to:

1. High Solids Polyurethane, B65 Series by Sherwin-Williams, 3.0 to 5.0 mils minimum dry film thickness.

2. Series 73 Endura-Shield by Tnemec, 2.0 to 5.0 mils minimum dry film thickness.

3. Or approved equal.

PART 3 - EXECUTION

3.01 SHOP FINISHING

A. Shop Finishing: Abrasion resistant coatings may be applied in the shop, before delivery to site.

3.02 EXAMINATION

A. Verification of Conditions: Examine substrates and conditions under which coatings will be applied for compliance with requirements on applying coatings. Surfaces to receive coatings shall be thoroughly dry before coatings are applied and meet coating manufacturer’s recommendations.

1. Do not proceed with coating application until unsatisfactory conditions have been corrected.
2. Start of application will be construed as the applicator's acceptance of surfaces within that particular area.

3.03 PREPARATION

A. Cleaning: Before applying coatings or other surface treatments, clean substrates of substances that could impair bond of the various coatings. Remove oil and grease prior to cleaning. Schedule cleaning and coating application so dust and other contaminants from the cleaning process will not fall on wet, newly coated surfaces

B. Surface Preparation:

1. Clean and prepare surfaces to be coated according to the manufacturer's instructions for each particular substrate condition and as specified, in conjunction with the galvanizer's post-treatment recommendations.
   a. Provide barrier coats over incompatible primers or remove and reprime. Notify the Resident Engineer in writing of problems anticipated when using the specified finish-coat material with substrates primed under other sections or other contracts.
   b. Clean galvanized metal surfaces; remove oil, grease, dirt, loose scale and other foreign substances. Use solvents that comply with the recommendations of the Society for Protective Coatings.
   c. Do not damage galvanized surfaces.

C. Material Preparation: Carefully mix and prepare materials according to the coating manufacturer's directions.

1. Maintain containers used in mixing and application of coatings according to the manufacturer's directions.

2. Stir materials before applying to produce a mixture of uniform density; stir as required during application. Do not stir surface film into the material. Remove films and, if necessary, strain the coating material before using.

3. Use only the type of thinners approved by the manufacturer and only within recommended limits.

3.04 APPLICATION

A. Application – General:

1. Apply abrasion resistant coatings by brush, roller, spray or other applicators except as specified otherwise herein, according to the manufacturer's directions. Use brushes best suited for the material being applied. Use rollers of carpet, velvet back, or high-pile sheep's wool as recommended by the manufacturer for the material and texture required.

2. Do not apply coatings over dirt, rust, scale, grease, moisture, scuffed surfaces, or conditions detrimental to forming a durable coating film.

3. Provide finish coats compatible with the primers used.

4. The number of coats and film thickness required is the same regardless of the application method. Do not apply succeeding coats until the previous coat has cured as recommended by the manufacturer. Where sanding is required, according to the manufacturer's directions, sand between applications to produce a smooth, even surface.
5. When undercoats or other conditions show through the final coat, apply additional coats until the cured film has a uniform coating finish, color and appearance. Give special attention to edges, corners, crevices, welds, exposed fasteners and similar surfaces to ensure that they receive a dry film thickness equivalent to that of flat surfaces.

B. Tinting: Tint each undercoat a lighter shade to facilitate identifying each coat where multiple coats of the same material are to be applied. Tint undercoats to match the color of the finish coat, but provide sufficient difference in shade of undercoats to distinguish each separate coat.

C. Scheduling Coating Application:
   1. Apply first coat to surfaces that have been cleaned, pretreated, or otherwise prepared for coating as soon as practical after preparation and before subsequent surface deterioration.
   2. Allow sufficient drying time between successive coats. Do not recoat until the coating has dried so it feels firm and does not deform or feel sticky under moderate thumb pressure and where applying another coat does not cause the undercoat to lift or lose adhesion or until manufacturer's requirements are met for recoating.

D. Application Procedures:
   1. Apply coatings by brush, roller, spray or other applicators according to the manufacturer's directions when not specifically specified herein.
   2. Apply primers and first coats by spray.

E. Minimum Coating Thickness: Apply each material no thinner than the manufacturer's recommended spreading rate. Provide total dry film thickness of the entire system as recommended by the manufacturer or specified herein.

F. Prime Coats:
   1. Before applying intermediate coats, apply a prime coat of material, as recommended by the manufacturer, to the material required to be coated or finished that has not been prime-coated under this or other sections.
   2. Recoat primed and sealed substrates where there is evidence of suction spots or unsealed areas in the first coat to ensure a finish coat with no burn-through or other defects caused by insufficient sealing.

G. Brush Application: Brush-out and work brush coats into surfaces in an even film. Eliminate cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness, or other surface imperfections. Neatly draw color breaks.

H. Mechanical Applications: Use mechanical methods to apply coating when permitted by the manufacturer's recommendations and governing regulations.
   1. Wherever using spray application, apply each coat to provide the equivalent hiding of brush-applied coats. Do not double-back with spray equipment, building-up film thickness of two coats in one pass, unless recommended by the manufacturer.
   2. Electrostatic application will be acceptable.
   3. Apply without cloudiness, spotting, laps, runs, sags, orange peel texture, or other surface imperfections.
I. Attach Labels to Parts Upon Completion of Painting.

J. Completed Work: Match approved samples for color, texture and coverage. Remove, refinish, or recoat Work not complying with specified requirements.

3.05 FIELD (SITE) QUALITY CONTROL

A. Field (Site) Tests and Inspections: The Resident Engineer reserves the right to invoke the following test procedure at any time and as often as the Resident Engineer deems necessary during coating operations.

1. Sound Transit will engage the services of an independent testing agency to sample the coating being used. Samples of material delivered to Project Site as well as applied, will be taken, identified, sealed and certified in the presence of the Contractor.

2. The testing agency will perform appropriate tests for the following characteristics as required by the Resident Engineer:

   a. Quantitative Materials Analysis.
   b. Absorption.
   c. Accelerated Weathering.
   d. Accelerated Yellowness.
   e. Adhesion.
   f. Color Retention.
   g. Alkali and Mildew Resistance.
   h. Abrasion Resistance.
   i. Apparent Reflectivity.
   j. Washability.
   k. Dry Opacity.
   l. Recoating.
   m. Skinning.
   n. Dry Film Thickness.

B. Non-Conforming Work: If results show materials being used do not comply with requirements, the Contractor may be directed to stop Work and remove non-complying materials, pay for testing, recoat surfaces coated with rejected materials, or remove rejected materials from previously coated surfaces.

3.06 CLEANING

A. At the end of each workday, remove rubbish, empty cans, rags and other discarded materials from the site.

B. After completing Work, clean spattered surfaces. Remove spattered coatings by washing, scraping, or other methods. Do not scratch or damage adjacent finished surfaces. Any
surfaces or items unable to be cleaned of coatings completely or that are damaged, shall be replaced or repaired at no cost to the Owner at the direction of the Resident Engineer.

3.07 PROTECTION
A. Protect Work of other trades, whether being coated or not, against damage from the coating operation. Correct damage by cleaning, repairing, replacing and recoating, as acceptable to the Resident Engineer. Leave in an undamaged condition.
B. At completion of other trades' construction activities, touch up and restore damaged or defaced coated surfaces.

3.08 COLOR SCHEDULE
A. Colors shall match the manufacturer's paint numbers listed in the Contract Documents, or as otherwise provided by Sound Transit.
B. Paint Schedule: Painted coatings shall be applied to galvanized steel OCS poles as listed in the Contract Documents, or as otherwise provided by Sound Transit. A sample table of relevant information to include in the Paint Schedule is shown below.

Table 1: Sample Table of Paint Schedule

<table>
<thead>
<tr>
<th>Drawing Number Prefix</th>
<th>Location</th>
<th>Stationing Start</th>
<th>Stationing End</th>
<th>Pole Type</th>
<th>Color and Reference</th>
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END OF SECTION
SECTION 34 23 13
OVERHEAD CONTACT SYSTEM STEEL POLES

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Requirements for the design, fabrication, furnishing, delivery, installation and testing of Overhead Contact System (OCS) galvanized steel poles.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. American Galvanizers Association (AGA)

2. American Institute of Steel Construction:
   a. AISC Manual of Steel Construction.
   b. AISC 303 - Code of Standard Practice for Steel Buildings and Bridges
   c. AISC 360 - Specification for Structural Steel for Buildings

3. American Society for Non-Destructive Testing

   b. ASTM A53 - Standard Specifications for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless.
   e. ASTM A153 - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware.
   f. ASTM A370 - Standard Test Methods and Definitions for Mechanical Testing of Steel Products.
   g. ASTM A384 - Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies.
   h. ASTM A500 – Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
i. ASTM A572 - Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel.

j. ASTM A595 - Standard Specification for Steel Tubes, Low-Carbon or High-Strength Low-Alloy, Tapered for Structural Use.


l. ASTM A992 – Standard Specification for Structural Steel Shapes.


5. American Welding Society (AWS):
   a. AWS D1.1 - Structural Welding Code – Steel.

6. Institute of Electrical and Electronics Engineers (IEEE)

1.03 SUBMITTALS

A. Submit:

1. Shop Drawings:
   a. Submit shop drawings for review giving complete information necessary for fabrication of the OCS poles.
   b. Indicate fittings, holes and accessories.
   c. Allocate the locations, sizes and types of welds.

2. Material Testing and Evaluation Reports:
   a. Certified copies of the laboratory test reports within five days after completion of each test or series of tests.

3. Welding Procedures:
   a. Submit the following:
      1) Specifications for welding procedures in accordance with AWS D1.1.
      2) Certificates of qualifications of welders, welding operators, and tackers in accordance with AWS D1.1.
      3) Certificates of qualifications of welding inspectors in accordance with AWS D1.1.

4. Proof of Compliance:
a. Before commencing fabrication, submit for review the manufacturer’s certificates of compliance, or certified laboratory test reports demonstrating compliance of raw materials and fabricated products with Article 2.02, herein.

5. Schedule:
   a. Schedule of shop drawing submittals, certified laboratory test reports, test dates, test locations, and test reports.

6. Methods:
   a. Methods of manufacture and installation including personnel and equipment.
   b. In areas adjacent to Washington State Highways, other roadways, or structures, submit diagrams illustrating the erection methods and clearances.

7. Pole Deflection Test Procedure and Test Report:
   a. Submit Pole Deflection Test Procedure with the following information.
      1) Step by step procedure for the test, as described in IEEE Std 1630.
      2) A table including pole type, load value, height of load applications, and calculated deflection for each pole type.
      3) List of equipment and measuring devices, including calibration documentation.
      4) Description of rigid mounting base.
      5) Test Procedure shall be signed and sealed by a qualified Professional Engineer registered in the State of Washington.
   b. Submit Pole Deflection Test Report with the following information.
      1) Submit the information listed above in the Pole Deflection Test Procedure.
      2) Include the actual measured loads and deflections from the test data.
      3) Include passed or failed, based on the requirements in IEEE Std 1630.
      4) Test Report shall be signed and sealed by a qualified Professional Engineer registered in the State of Washington.

8. Galvanizing Repair:
   a. Submit product data for field repair of damaged galvanized surfaces.
   b. Submit procedure for performing field repair of damaged galvanized surfaces.
1.04 QUALITY ASSURANCE

A. Testing and Inspection:

1. Material Testing:
   a. Contractor shall provide chemical compositions and mechanical properties of materials specified herein as proof of compliance, either by obtaining the manufacturer's certificates of compliance or by laboratory testing at a facility approved by the Resident Engineer.

2. Weld Testing:
   a. Weld Testing Requirements:
      1) Weld testing shall conform to the requirements listed in IEEE Std 1630, as summarized below.
      2) Provide the services of an AWS Certified Welding Inspector to:
         a) Inspect fabrication operations.
         b) Inspect welding procedures.
         c) Inspect welds made by welding personnel.
      3) Perform weld testing on not less than 5 percent of each type of OCS pole selected at random by Resident Engineer.
      4) Test poles by ultrasonic, radiographic, and magnetic particle methods as specified below.
         a) Equipment, procedures, and personnel for weld testing and test reports to conform to the requirements of AWS D1.1.
         b) Ultrasonic testing conforming to the requirements of AWS D1.1. Perform ultrasonic test on the complete penetration welds between the pole shaft and pole base and on circumferential welds in the pole shaft.
         c) Radiographic testing shall be performed on all seam welds of tubular poles.
         d) Magnetic particle testing conforming to the requirements of ASTM E709. Perform magnetic particle test on other welds, including longitudinal seam welds and welds at handholes, cable outlets and other welded on attachments and reinforcements.
      5) For each tested pole that is found to be unacceptable, perform weld testing on a further sample of two poles, selected at random by the Resident Engineer.
      6) Results of weld testing to be deemed acceptable or unacceptable in accordance with AWS D1.1.
      7) Repair welds found to be unacceptable in accordance with AWS D1.1 and retest.
3. Impact Testing:
   a. Test structural steel materials for base plates and pole shafts for impact toughness in accordance with the Charpy V-notch test in conformance with ASTM A370 and ASTM E23.
   b. The minimum energy value to be 15 feet-pounds at zero degrees Fahrenheit.

4. Galvanizing Testing:
   a. Inspect galvanized items for conformance with the requirements of the following ASTM Specifications as applicable:
      2) Embrittlement: ASTM A143.

5. Pole Deflection Testing:
   Demonstrate to the Resident Engineer the acceptable deflection values of each type of pole furnished under this Contract.
   a. Demonstration shall be in the form a factory test, performed at the place of manufacture or other suitable location.
   b. Testing shall be nondestructive and at a place and time agreed by the Resident Engineer.
   c. Conduct the test on a rigid foundation that resists translation and rotation in any axis.
   d. The test shall be performed as described in IEEE Std 1630.

PART 2 - PRODUCTS

2.01 DESIGN
   A. Multi-Ply Tubular Poles:
      1. Where multi-ply tubular poles are proposed by the pole Manufacturer, the Manufacturer shall perform the necessary design and calculations to ensure that the pole deflection shall meet the following criteria.
         a. The deflection at the top of the pole shall not exceed L/40 when a load equal to the allowable bending moment divided by the height of the pole is applied at the top of the pole.
         b. The deflection at a height of 20 feet shall not exceed 1 inch under the worst case live loading, where live load is defined as the difference between the radial loads of the worst case operating conditions minus the standard installation conditions, applied at an assumed height of 23 feet.

2.02 MATERIALS
   A. Tubular Poles:
1. Fabricate tubular pole shafts, handholes, reinforcements, and covers from one of the following structural steel material types:
   a. ASTM A572, Grade 50, 55, 60 or 65.
   b. ASTM A595, Grades A or B.

2. Vandal/Tamper Resistant Hardware:
   a. Hardware and fastening devices including screws, nuts and bolts shall be vandal/tamper resistant and shall prevent unauthorized tampering and/or disassembly of completed pole installations.

3. Base Plates:
   a. Fabricate base plates from structural steel conforming to ASTM A572 Grade 50.
   b. The minimum yield stress capacity of the base plate steel shall meet or exceed the yield stress capacity of the pole shaft steel.

4. Pole Caps:
   a. Provide pole caps on tubular poles fabricated from galvanized pressed steel, fitted with three tamper resistant stainless steel set screws conforming to ASTM F593.

5. Feeder Spouts:
   a. Provide feeder spouts fabricated from standard steel pipe conforming to ASTM A53, Type S, Grades A or B.

6. Pole Penetrations:
   a. Holes in tubular poles and support structures shall be pre-drilled prior to hot-dip galvanization. No field drilling is allowed without explicit approval by the Resident Engineer.

7. Handhole Cover Screws:
   a. Provide tamper-resistant stainless steel Allen set screw type handhole cover screws conforming to ASTM F593.
   b. Tapped holes in the handhole frames may be furnished in lieu of nuts welded to the handhole frames.

8. Feeder Spout Box Screws:
   a. Provide tamper-resistant hex head stainless steel cap screw type feeder spout box screws conforming to ASTM F593.

B. Wide Flange Poles:

1. Pole Shafts:
   a. Fabricate wide flange pole shafts from structural steel conforming to ASTM A992 Grade 50.
   b. OCS poles shall have no spliced joints.
2. Base Plates:
   a. Fabricate base plates from structural steel conforming to ASTM A572 Grade 50.
   b. The minimum yield stress capacity of the base plate steel shall meet or exceed the yield stress capacity of the pole shaft steel.

3. Galvanizing Coatings:
   a. Hot-dip galvanizing shall be in accordance with ASTM A123 for fabricated pole assemblies.

C. Galvanizing Repair:
   1. Repair according to ASTM A780.
   2. Manufacturers/Products:
      a. Galvaloy by Metalloy Products Co., Hardhat 2185 by Rust-Oleum, ZRC by ZRC Chemical Products, or approved equal.

D. OCS Pole Paint:
   1. OCS pole painting shall be in accordance with Section 34 23 05 OCS Pole Painting.

2.03 ABRICATION

A. General:
   1. Fabricate poles, fittings and accessories to the dimensions indicated in the Contract Documents.

B. Methods and Tolerances:
   1. Fabricate poles, fittings and accessories by methods and within tolerances conforming to the tolerances listed in IEEE Std 1630, except as indicated in the Contract Documents.

   2. Tubular Pole Diameter:
      a. Pole diameter shall be within 1/8 inch of the design diameter.
      b. Round poles shall be within 1/16 inch of perfect round.

   3. Tubular Pole Wall Thickness: Pole wall thickness shall be within plus 10 percent or minus 5 percent of the design thickness.

   4. Tubular Pole Taper:
      a. Pole taper shall be constant for the length of the pole with maximum taper of 0.14 inches per foot as indicated in the Contract Documents.

   5. Wide Flange Pole Dimensions:
      a. Dimensional tolerances shall conform to AISC 303, unless specified otherwise below.

   6. Straightness:
a. Straightness shall be within 1/8 inch per 5 feet of pole length.

7. Length:
   a. Pole length shall be plus 2 inches and minus zero inches.

8. Base Plates:
   a. Bolt Circle: Plus 1/16 inch minus 0 inch.
   b. Hole Diameter: Plus 1/16 minus 0 inch.
   c. Location of Holes: Plus 1/16 inch in each direction.

C. Welding Procedures:
   1. Welding procedures, welders, welding operations and tackers shall conform to AWS D1.1.
   2. Repair welds found to be unacceptable in conformance with the provisions of AWS D1.1.

D. Surface Grinding:
   1. Before galvanizing, smooth needle chip and grind welds to eliminate surface cracks.
   2. Deep grind marks shall be removed, eliminate sharp edges and burrs, and any excessive pitting.

E. Drain/Relief Holes:
   1. Drill the inner plies of multiple-ply poles to provide drain/relief holes for use during galvanizing.
   2. Arrange holes so that the strength of the pole is not reduced.

F. Galvanizing:
   1. After fabrication, hot-dip galvanize the poles, fittings, and accessories inside and out in conformance with ASTM A123 or ASTM A153.
   2. Galvanize pole fabrications for their entire length at one time in a single hot-dip galvanizing bath.
   3. Galvanizing by successive dipping of partial pole lengths will not be permitted.
   4. Conform to ASTM A143 to prevent embrittlement of the steel.

G. Straightness:
   1. After galvanizing, when the poles have cooled to ambient temperature, straighten the poles as necessary to conform to the requirements indicated in the Contract Documents.
   2. Straightening methods shall not require heating of the poles and shall not damage the zinc coating.
   3. Galvanizing shall be performed by a company that is a member of the AGA.
1. Stamp on top of base plate or weld a manufacturers’ pole identification sign to each pole immediately after fabrication including:
   a. Pole type.
   b. Manufacturer.
   c. Date of manufacture.

I. Painting:
   1. Refer to Section 34 23 05 OCS Pole Painting.

PART 3 - EXECUTION

3.01 DELIVERY, STORAGE AND HANDLING
   A. Deliver poles complete with associated fittings and accessories, properly packed and protected against damage and loss of parts.
   B. Protect from damage during storage, handling, and moving from the storage facility to the installation site.
   C. Handle and transport poles in a manner to preclude damage to either the structural steel, paint, or the zinc coating.

3.02 INSTALLATION
   A. General:
      1. Install poles as indicated in the Contract Documents.
      2. Ensure equipment and personnel maintain a 10 foot distance from energized OCS wires, or any other types of overhead wires.
      3. Contractor shall arrange any required power de-energization with Sound Transit and King County Metro.
      4. Installation shall comply with State, Federal, and Local requirements.
      5. Do not set the poles less than seven days after foundations are installed and do not load to the design requirements less than 30 days after foundations are installed.
   B. Preparation of Foundations:
      1. Steel poles are anchor base type for installation on foundations constructed with projecting anchor rods.
      2. Before setting poles, clean anchor rods and inspect the pole foundations for structural soundness, correct location, and correct foundation type. Report any deficiencies to Resident Engineer for disposition thereof.
   C. Pole Rake:
      1. Rake anchor base steel poles by means of double nuts and washers, with two nuts and washer above, and with one nut and washer below the base plate. The final rake of the pole shall be defined as the rake of the pole when all OCS wiring, cantilevers, and any other items attached to the OCS pole have been
installed in their final state. The final rake of the pole shall ensure that the pole is within 1 inch of plumb, when measured at the top of pole, under standard installation conditions.

D. Handhole Locations:
   1. Set poles with handholes on the opposite side of approaching vehicle traffic under normal operating conditions, except on center poles, where they will face in the direction of decreased stationing.

E. Fittings:
   1. Furnish and install fittings required for the specific installation, including, but not limited to, the following items.
      a. Handholes with cover, gasket and tamper-resistant screws.
      b. Feeder spouts and caps.
      c. Pole caps (special pole caps as required).
      d. Grounding studs.

F. Feeder Poles:
   1. Fit feeder poles with cable supports and terminating bushing at the cable entrance hubs of the weatherproof, compression seal type.
   2. Install feeder poles with the spout facing the track where the feeder cables will be connected.

G. Grounding and Bonding:
   1. Bond steel poles to the foundation ground as indicated elsewhere in the Contract Documents.
   2. Repair damage to the steel pole base plate galvanized coating in accordance with Article 3.03, herein.

H. Additional Requirements:
   1. Exercise care during erection of tubular and wide flange poles to prevent damage or disfigurement. Repair imperfections as necessary to restore poles to a condition acceptable to the Resident Engineer.
   2. Touch-up damage to galvanized and paint coatings as directed by the manufacturer’s written directions.

3.03 TOUCH UP
   A. Immediately after erection, remove shop coating from field welds and bolted connections.
   B. Brush coat areas of damaged galvanizing with galvanizing compound applied in accordance with manufacturer’s instructions.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Procurement, delivery and installation of assemblies, components and fittings that make up the OCS.
   a. Work includes furnishing and installing of OCS Systems in accordance with approved OCS Layout Drawings, Bill of Materials, and OCS Drawings contained in the Contract Drawings and Specifications, and with Contractor’s detailed design.
   b. Equipment to be provided may include OCS pole and portal brackets, conductors, surge arresters, conductor rail, cantilevers, headspans, cross spans, hangers, feeders, jumpers, terminations, conductor tensioning devices, sectioning equipment, tunnel supports, anchor attachments, head and down guys, and other overhead contact system components.
   c. OCS equipment is energized at a nominal 1500 Vdc and shall be double insulated.
   d. OCS equipment shall be manufactured, prefabricated, installed and tested using industry standards and best practices.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. Pertinent provisions of NEMA, IEEE, and ANSI shall apply to the Work of this Section.

2. American Galvanizers Association (AGA)

3. American Institute of Steel Construction (AISC)
   a. AISC 303 - Code of Standard Practice for Steel Buildings and Bridges
   b. AISC 326 - Detailing for Steel Construction

4. American National Standards Institute (ANSI)
   a. ANSI/NEMA C29.1 - Test Methods for Electrical Power Insulators including Addenda C29.1a and C29.2a
   b. ANSI Z55.1 – Gray Finishes for Industrial Apparatus and Equipment

5. American Society of Mechanical Engineers (ASME)
   a. ASTM A6/A6M - Standard Specifications for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
   b. ASTM A29/A29M - Standard Specification for General Requirements for Steel Bars, Carbon and Alloy, Hot-Wrought
   c. ASTM A36/A36M - Standard Specification for Carbon Structural Steel
   d. ASTM A47/A47M - Standard Specification for Ferritic Malleable Iron Castings
   e. ASTM A48/A48M - Standard Specification for Gray Iron Castings
   f. ASTM A53/A53M - Standard Specification for Pipe, Steel Black and Hot-Dipped, Zinc-Coated Welded and Seamless
   g. ASTM A108 - Standard Specification for Steel Bars, Carbon and Alloy, Cold Finished
   h. ASTM A123/A123M - Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   i. ASTM A143/A143M - Standard Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
   j. ASTM A153/A153M - Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
   k. ASTM A240/A240M - Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate Sheet, Sheet, and Strip for Pressure Vessels and for General Applications
   l. ASTM A283/A283M - Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
   m. ASTM A368 – Standard Specification for Stainless Steel Wire Strand
   n. ASTM A384/A384M - Standard Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
   o. ASTM A385/A385M - Standard Practice for Providing High Quality Zinc Coatings (Hot-Dip)
   q. ASTM A500/A500M – Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Round Shapes
   r. ASTM A501/A501M - Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
   s. ASTM A555 – Standard Specification for General Requirements for Stainless Steel Wire and Wire Rods
t. ASTM A563/A563M - Standard Specification for Carbon and Alloy Steel Nuts

u. ASTM A568/A568M - Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low Alloy, Hot-Rolled and Cold-Rolled, General Requirements for

v. ASTM A572/A572M – Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel

w. ASTM A575 - Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades

x. ASTM A576 - Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality

y. ASTM A580 – Standard Specification for Stainless Steel Wire

z. ASTM A1011/A1011M - Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

aa. ASTM A1085/A1085M – Standard Specification for Cold-Formed Welded Carbon Steel Hollow Structural Sections (HSS)

bb. ASTM B1- Standard Specification for Hard-Drawn Copper Wire

c. ASTM B3 - Standard Specification for Soft or Annealed Copper Wire

d. ASTM B6 - Standard Specification for Zinc

e. ASTM B8 - Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

ff. ASTM B47 - Standard Specification for Copper Trolley Wire

gg. ASTM B173 - Standard Specification for Rope-Lay-Stranded Copper Conductors having Concentric-Stranded Members, for Electrical Conductors


ii. ASTM B231/B231M – Standard Specification for Concentric-Lay-Stranded Aluminum 1350 Conductors


ll. ASTM B498/B498M – Standard Specification for Zinc-Coated (Galvanized) Steel Core Wire for Use in Overhead Electrical Conductors

mm. ASTM B500/B500M – Standard Specification for Metallic Coated Aluminum Clad Stranded Steel Core for Use in Overhead Electrical Conductors
1.03 SUBMITTALS

A. Submit:

1. Product Data: Complete manufacturer’s data including certification that product has been designed, manufactured, inspected and tested in accordance with the referenced standards and Specifications.

   a. Stainless Steel Wire Rope:
      1) Size.
      2) Type.
      3) Material.
      4) Number of and diameter of individual wires.
      5) Overall diameter.
      6) Cross-section area.
      7) Weight per foot.
      8) Rated breaking load.
      9) Manufacturer’s data and usage procedures and tools used to grip wire during installation.

   b. Contact Wire:
1) Size.
2) Type.
3) Material.
4) Overall diameter.
5) Cross-section area.
6) Weight per foot.
7) Ampacity.
8) Rated breaking load.
9) Manufacturer’s data and usage procedures and tools used to grip wire during stringing and when held under tension.

c. Messenger Wire:
1) Size.
2) Type.
3) Material.
4) Number of and diameter of individual wires.
5) Overall diameter.
6) Cross-section area.
7) Weight per foot.
8) Rated breaking load.
9) Ampacity.
10) Manufacturer’s data and usage procedures and tools used to grip wire during stringing and when held under tension.

d. Jumper Wire:
1) Size.
2) Type.
3) Material.
4) Number of and diameter of individual wires.
5) Overall diameter.
6) Cross-section area.
7) Weight per foot.
8) Rated breaking load.
9) Ampacity.
e. Insulators and insulated cable:
   1) Voltage rating.
   2) Insulation Level.
   3) Creepage Distance.
   4) Withstand Voltage, Wet and Dry.
   5) Storage and handling instructions.
   6) UV rating.
   7) Rated breaking load.

f. Section Insulators: Provide data to show that insulator material is resistant to ultra-violet radiation and electrical tracking.
   1) Voltage rating.
   2) Insulation Level.
   3) Creepage Distance.
   4) Withstand Voltage, Wet and Dry.
   5) Storage and handling instructions.
   6) UV rating.
   7) Rated breaking load.

g. Submit other products supplied by Contractor but not specified.

h. Warning signs and attachment.
   1) Dimensions.
   2) Material.
   3) Attachment method.

i. Brackets
   1) Dimensions.
   2) Materials.

j. Cantilever Pipe
   1) Dimensions.
   2) Materials.

2. Shop Drawings:

   a. General Requirements:
      1) Show details of components including load ratings, dimensions, weights and installation instructions.
2) Each shop drawing shall have a bill of materials listing components with part or catalog number, descriptive text, quantity required and unit of measure.

3) Components shown in Contract Drawings are generic. Provide standard assemblies and components that meet the calculated dimensional and loading requirements for approval.

4) Both assembly and component shop drawings shall bear the seal of a qualified professional engineer registered in the State of Washington.

b. Assembly Shop Drawings:

1) Down Guy Anchor Plates.
2) Support Assemblies, Drop Pipes, and Drop Vertical Supports.
3) Eyebolts and Anchor Bolts.
4) Cantilevers.
5) Headspans.
6) Cross spans.
7) Span Wire and Portal Registrations.
8) Pull offs.
9) Tunnel Supports.
10) Section Insulators.
11) Feeder Connections.
12) Balance Weights.
13) Fixed Anchors.
14) Y-Terminations.
15) Spring Terminations.
16) Knuckles.
17) Contact Bridges.
18) Jumpers.
19) In-Span Insulators.
20) Splices.
21) Midpoint Anchors.
22) Bridles.
23) Downguys and Headguys.
24) Hangers.
25) Brackets, Pole Bands and Pole Slings.
26) Anchor Brackets.
27) OCS Monitoring System.
28) Warning Signs and attachment method.

c. Components, Fittings, and Hardware Shop Drawings:
   1) Provide a drawing for each individual component, fitting, and hardware item, and for each small assembly of components where assembly is typically supplied as one unit by OCS parts manufacturer.
   2) Drawings shall be organized in catalog format, bound and covered, in 8.5 by 11 (letter) size paper. The format shall include:
      a) Drawing index in alphabetical or numerical order.
      b) Assembly to component matrix.
      c) Component to assembly matrix.
      d) Components grouped and tabbed by like items, (e.g. wire, turnbuckles, fittings, clamps).
      e) One component per page.

d. Submit shop drawings for the fabrication and erection of assemblies of metalwork not completely substantiated by the manufacturer's data sheets. Include plan elevations at not less than 1 inch to 1 foot scale and include details of sections and connections at not less than 3 inch to 1 foot scale.

e. Drawings for temporary anchorages, guying, and electrical isolation for information prior to installation.

f. Record Documents: Full set of OCS Layout Drawings and structure cross section drawings, to show as built dimensions and details.

g. Shop Drawings shall include at minimum:
   1) Title block.
   2) Description of component, including materials composing various parts.
   3) Dimensions in English units of both metal and insulating parts.
   4) Mechanical properties, including working and ultimate strengths.
   5) Installation torque values.
   6) Electrical properties, if used for electrical insulation.
   7) Ultraviolet properties, if non-metallic material.
8) Minimum two views of the component.

9) Scale of drawing.

10) Applicable standards and references.

11) Suppliers catalog number.

12) Original equipment manufacturer’s name and part number.

h. OCS Cross Sections:

1) Submit cross sections of portals, headspans and cross spans.

2) Cross sections shall depict accurate dimensions and components used at each location.

3) Cross section drawings shall include the following technical information at a minimum:
   a) Wire tensions for headspans and cross spans.
   b) Hanger lengths.
   c) Pipe lengths.
   d) Portal and/or Pole types.
   e) Offset of MW and CW support from centerline of track.
   f) Stagger of contact wire
   g) Height and length of support in reference to track centerline.
   h) Dimensions to civil structures.
   i) Anchoring method and dimensions.

i. Cantilever tube dimension drawings.

j. Drawings for temporary anchorages, guying, and electrical isolation for information prior to installation.

3. Samples:

   a. Samples that are not destroyed will be returned to Contractor.

   b. One initial sample and up to a maximum of five samples of each listed components as requested by the Resident Engineer:

      1) Brackets and hinges.
      2) Tunnel supports.
      3) Termination components.
      4) Conductor clamps, including contact wire clamps.
      5) Insulators.
6) Section insulators.
7) Insulated cable.
8) Castings.
9) Fittings.
10) Surge arresters.
11) OCS monitoring system components.
12) Warning Signs.
13) Other items upon request by the Resident Engineer.

4. Certificates of Compliance:
   a. Insulators (including section insulators):
      1) Steel analysis.
      2) Hot-dip galvanizing.
      3) Adhesive materials.
      4) Insulator materials.
      5) In-service record of proposed insulators.
      6) Certified quality control procedures used in the manufacturing process.

5. Schedules:
   a. Wire Schedules: List contact and messenger wire runs and include the following information:
      1) Begin stationing.
      2) End stationing.
      3) Wire run length.
      4) Reel numbers.
      5) Length of wire on reel.

6. Procedures:
   a. Procedures for each stage of OCS installation.
   b. Procedure for pre-stressing contact wire.
   c. Installation procedures for section insulators including procedures for hanger adjustment and hogging of section insulator.
   d. Anchoring and installation methods for tunnel supports and tunnel anchor brackets.
e. Jumper length tables for prefabrication and installation.

f. Installation procedures and adjustment procedures where applicable for the following:
   1) Insulators.
   2) Brackets and Hinges.
   3) Balance Weight Assemblies.
   4) Spring tensioner assemblies.
   5) OCS monitoring system.

7. Construction Work Plans:
   a. List of construction work plans.
   b. Construction work plan for each stage of OCS installation.
   c. Construction work plan for tie in to existing Link system.
   d. Construction work plan for work near roadways.

8. Conductor Erection Spreadsheet:
   a. Submit Conductor Erection Spreadsheet template.
   b. Submit updated Conductor Erection Spreadsheet within 5 days after installation of each conductor.

9. Qualifications Statements:
   a. Personnel Qualifications: Submit qualifications and proof of experience for OCS Installation Supervisor and OCS Installation Crew Foremen for approval by the Resident Engineer prior to mobilization of installation personnel.
   b. Welder Certifications and Qualifications: Submit welder certifications and qualifications as required by AWS D1.1.

10. Test and Evaluation Reports:
   a. Factory Design and Production Tests: Submit certified testing reports from factory design tests and factory production tests specified in Section 34 23 69, Overhead Contact System Testing.

1.04 QUALITY ASSURANCE

A. Manufacturer Qualifications:
   1. Original equipment manufacturer (OEM) of OCS components shall be regularly engaged in the manufacture of such components.
   2. OEM shall have at least 5 years of experience in successfully providing OCS products.
   3. OEM shall certify that products are suitable for the application for which they are proposed for the work.
B. General Qualifications:

1. Licensing and Certification Requirements:
   a. All work specified in this shall be performed by workers skilled and experienced in the installation of OCS systems.
   b. Welding shall be done by qualified, certified, welders who make only those welds for which they have been qualified in accordance with AWS D1.1, or other approved qualifying procedures. Records of welder qualification tests shall be made available for review upon request from the Resident Engineer.

2. OCS Installation Supervisor Qualifications:
   a. An OCS Installation Supervisor shall be appointed to supervise the complete OCS installation, field testing, and commissioning of the OCS equipment provided under this Contract.
   b. The OCS Installation Supervisor shall have a minimum of 10 years experience as a superintendent or general foreman in charge of OCS installations.
   c. The OCS Installation Supervisor shall not be the same person designated to be the Traction Power Installation Supervisor.
   d. The OCS Installation Supervisor shall be trained and qualified for installation by the OCS equipment manufacturer.

3. OCS Installation Crew Foreman Qualifications: OCS foreman shall be qualified by experience and training to perform the specified work, and shall be outside linemen who are employees of a Washington licensed electrical Contractor. The foreman shall have at least 10 years of experience in the installation of OCS and demonstrated experience as a foreman of OCS installations or similar overhead line work.

4. OCS Installer Qualifications: OCS installers shall be qualified by experience and training to perform the specified work, and shall be outside linemen who are employees of a Washington licensed electrical Contractor. A Journeyman Lineman shall have completed a State of Washington or federally approved Outside Line Construction and Maintenance apprenticeship program of 6000 hours of on-the-job training.

5. Personnel Performing Nondestructive Testing: American Society for Nondestructive Testing Certified NDT. Only personnel certified for NDT Level I and working under a NDT Level II person or persons certified for NDT Level II may perform nondestructive testing.

1.05 DELIVERY, STORAGE AND HANDLING

A. Deliver materials and equipment to job site in unbroken packages, reels, or other forms of containers. Package insulators to prevent damage during transport and installation.

B. Wire and Cable: Ship wire, wire rope, and cable on suitable reels. Each reel shall have a strong, weatherproof tag securely fastened to it giving physical and mechanical properties as well as material type designation, Standard designation, and name and mark of manufacturer.
PART 2 - PRODUCTS

2.01 GENERAL REQUIREMENTS

A. Products to be purchased shall be identified by the Contractor and quantified in the Bill of Materials. The Contractor shall make allowances for wastage and breakages.

B. Insulation:
   1. OCS equipment shall be double insulated. Provide a minimum of two levels of electrical insulation between contact wire and a grounded structure.
   2. Provide a minimum of 5-inch air gap between energized parts and a grounded structure.

C. Substitutions: If other types of materials are proposed, Contractor shall, along with product description, include relevant standards and information on that material in the submittal. Substitution Procedures shall be as stated elsewhere in the Contract Documents.

2.02 ASSEMBLIES

A. Down Guy Anchor Plates:
   1. Shall be manufactured from ASTM A572 Grade 50.
   2. Shall be hot dipped galvanized.

B. Support Assemblies, Drop Pipes, and Drop Vertical Supports:
   1. Design the support assemblies, drop pipes, and drop vertical assemblies to match the structure it is attached to.
   2. Shall be hot dipped galvanized.

C. Eyebolts and Anchor Bolts:
   1. Refer to Section 34 23 25, OCS Anchorage to Concrete for concrete anchor details.

D. Cantilevers:
   1. The type of cantilever to be installed at each location shall be according to the layout plans.
   2. Double insulation shall be provided.

E. Headspans:
   1. Provide two or more stainless steel span wires.
   2. Provide double insulation between energized conductors and grounded structures as well as between catenary sections fed from different sources.
   3. Provide turnbuckles that have a minimum of 6 inches of adjustment capability in each direction after installation.

F. Cross spans:
1. Provide a single stainless steel wire with double insulation. Provide cross spans and span guys on single contact wire segments and design for single and multi-track arrangements.

2. Cross span and span guy wires shall be easily adjustable with turnbuckles to facilitate installation, adjustment and future maintenance and shall have at least 6 inches of adjustment in each direction, after installation.

3. Single contact wire systems suspended from cross spans shall use a bridle to support contact wire on either side of the suspension point.

4. Design cross spans and span guys for site specific loading conditions.

5. Provide stainless steel wire for cross spans.

G. Span Wire and Portal Registrations:

1. Shall provide the required insulation levels to ensure the entire span or portal assembly is double insulated between the energized catenary and any grounded structure.

H. Pull Offs:

1. Provide wire pull-offs suitable for single and multiple track operations.

2. Provide pull-off assemblies to hold the OCS system in its correct alignment on curves.

3. Design and determine tensions and attachment heights of the pull offs.

4. Provide stainless steel wire for assemblies.

5. Design pull offs to accommodate loads at each location within specified temperature range as shown in the Contract Drawings.

I. Tunnel Supports:

1. Shall be designed to provide adequate clearance to other live fittings, pantographs, the dynamic vehicle envelope, and all other discipline’s hardware in the tunnel.

J. Section Insulators:

1. Provide section insulators that provide smooth passage of vehicle pantograph with minimum current interruption by pantographs at running speeds up to 55 mph.

2. Bridging type section insulators shall permit continuous current collection during passage of vehicle pantograph by using overlapping conductive runners as shown in the Contract Drawings.

3. Non-bridging type section insulators shall insure that adjacent sections of Overhead Contact System shall remain electrically isolated from each other during each passage of a vehicle pantograph.

4. Section insulators shall meet or exceed the following design requirements:

   a. Design shall be suitable for use by new pantograph carbons and by carbons with 1 inch of wear.
b. Design shall ensure that electrical separation between adjacent contact sections is maintained at all times, electrically isolating one section from the other.

c. The section insulator shall be designed to remain stable (dynamically and structurally) for train operations under sustained crosswinds of 55 miles per hour.

d. The section insulator shall be designed to withstand crosswinds of up to 70 mph without failure, including permanent deformation.

e. Design shall ensure that moving pantograph is continuously in contact with section insulator.

f. Pantographs drawing current while traversing the section insulator shall not cause excessive arcing or damage to the section insulator or pantograph.

g. The design shall allow for torsional forces resulting from the passage of pantographs at 20 mph combined with lateral wind loads.

h. Contact wire skids or runners shall be copper or copper alloy and shall provide a smooth transition from one section to another.

i. The section insulator shall be fitted with arcing horns. The arcing horns shall be configured to disperse an arc away from any assembly, wire or structure that may be damaged by the arc. The arcing horns shall be easily replaceable.

j. The design of the section insulator shall satisfy the required factors of safety listed in Section 34 23 01, Overhead Contact System General Requirements.

K. Feeder Connections:

1. Connections to conductors shall be of copper or bronze.

2. Jumper Clamps: Two bolts per clamp, or two single bolt clamps.

L. Balance Weights:

1. Shall automatically regulate tension of wires.

2. Shall operate freely within specified temperature range as shown in the Contract Drawings.

3. The catenary system balance weight anchor assembly shall operate at a nominal pulley ratio of 1:3.

4. In the event of a loss of catenary the balance weight shall be equipped with a stopping mechanism that holds the weight stack from dropping all the way to the ground and damaging the foundation of the pole.

5. Bearings in the pulley(s) shall be permanently sealed to prevent the ingress of moisture or other contaminants, or the loss of lubricant. Grease nipples shall be provided to permit field replenishment of lubricant during maintenance.

6. The tension wheel shall be cast bronze or aluminum.
7. Tolerance on weight of the complete balance weight stack shall be within 50 pounds of the required weight, but not less than the required weight.

8. All external ferrous parts shall be stainless steel or hot-dip galvanized in accordance with ASTM.

9. Each tensioning device shall bear the manufacturer’s name or trademark and year of manufacture clearly and permanently.

M. Fixed Anchors:
1. Provide strain type termination assemblies of a straight-line design or of other design of aesthetically pleasing appearance.

2. Automatic terminations shall be as shown on the drawings.

3. Provide cone or wedge type designs. Include turnbuckles with a minimum of 6 inches of adjustment capability in each direction after installation where required. Slip strength of the assembly shall meet 100 percent of the breaking strength of the terminating conductor.

N. Y-Terminations:
1. Provide y-termination assemblies to terminate the catenary at the end of the alignment between multiple poles.

2. Design and determine the tensions and attachment heights of the y-terminations.

3. Design y-terminations to accommodate loads at each location within specified temperature range as shown in the Contract Drawings.

O. Spring Terminations:
1. Spring tensioners shall be rated for the specified application shown in the Contract Drawings.

P. Knuckles:
1. Shall allow for differential along track movement between the catenaries.

Q. Contact Bridges:
1. Provide contact bridges for crossing of contact wires in crossovers and other areas where in running contact wires cross each other as shown on the Contact layout drawings.

2. Double clamp contact bridges at each end.

3. Contact bridge rod material shall be a shop straightened piece of contact wire.

R. Jumpers:
1. Connections to conductors shall be of copper or bronze.

2. Jumper Clamps: Two bolts per clamp, or two single bolt clamps.

S. In-Span Insulators:
1. Runnable type insulators shall be used where vertical separation between in-running and out-of-running contact wires is less than 3 inches.
2. Shall be designed to accommodate the loads within the specified temperature range as shown in the Contract Drawings.

T. Splices:
1. Messenger wire splices shall be crimp style and designed to accommodate the loads within the specified temperature range as shown in the Contract Drawings.
2. Contact wire splices shall be a bolted style and designed to accommodate the loads within the specified temperature range as shown in the Contract Drawings.

U. Midpoint Anchors:
1. Insulation in the midpoint anchors shall be installed as shown in the Contract Drawings.
2. Design and determine tensions and attachment heights of midpoint anchors.
3. Provide stainless steel wire for assemblies.

V. Bridles:
1. Provide wire bridles suitable for single and multiple track operations.
2. Provide bridle assemblies to hold the OCS system in its correct alignment on curves.
3. Design and determine tensions and attachment heights of overhead bridles.
4. Suitable bull-rings may be used in bridle systems to achieve correct tension distribution and accommodate the angles required. If bull-rings are not used, the fittings utilized shall not cause kinking or detrimental stresses in the bridle wire.
5. Provide stainless steel wire for assemblies.
6. Design pull offs to accommodate loads at each location within specified temperature range as shown in the Contract Drawings.

W. Downguys and Headguys:
1. Provide a turnbuckle for adjustment
2. Shall be made of stainless steel wire
3. Design downguys and headguys to accommodate loads at each location within specified temperature range as shown in the Contract Drawings.

X. Hangers:
1. Hangers with bolted-type messenger and contact wire clips.
2. Typical Hanger: Minimum hanger wire diameter of 1/8 inch, stainless steel with a loop at top to pass over messenger saddle.
3. Hanger Insulation: Install insulation in typical hanger. Insulation shall be rated to the requirements of Subparagraph 2.03 A.2. Messenger saddle shall be insulated and shall retain hanger loop securely irrespective of rotational disposition of saddle.
4. Thimbles shall be insulated with UV stabilized material that resists degradation.
5. Hangers shall be allocated by hanger sets that will include all hangers for a span of a specific length.

6. Determine all hanger lengths for Simple Catenary System.

Y. Brackets, Pole Bands and Pole Slings:
   1. Brackets shall be clearly distinguished to be for support attachments, or other light loads.
   2. All brackets shall utilize hinges and pins to promote free movement of the attached OCS assembly.
   3. All brackets shall be hot dipped galvanized.
   4. Pole bands for cantilevers on tubular poles may utilize stainless steel banding.
   5. Pole slings shall be made from stainless steel wire rope.
   6. Manufacture steelwork for support assembly to obtain conductor design heights.
   7. All bracket shop drawings shall show both maximum working load and breaking loads.

Z. Anchor Brackets:
   1. Anchor brackets shall be clearly distinguished to be for anchor loads or for support attachments.
   2. Anchor brackets comprised of framing channel shall be stainless steel.
   3. All manufactured steel anchor brackets shall be hot dipped galvanized.
   4. All anchor bracket shop drawings shall show both maximum working load and breaking loads.

AA. Warning Signs:
   1. Manufacture Warning signs, pole I.D. numbers, and information markers and materials for outdoor use. Demonstrate that no appreciable discoloration, cracking, blistering or dimensional change will occur for a period of not less than 10 years.
   2. Identification signs shall be fabricated of Grade 302 stainless steel and mounted as indicated.

2.03 COMPONENTS

A. Insulators:
   1. Design:
      a. Prepare detailed designs for each of the required insulators shown on Contract Drawings.
      b. Designs shall be based on performance requirements, working loads and basic dimensions and design shall be subject to review by the Resident Engineer.

   2. Insulators Ratings:
a. Nominal System Voltage 1500 Vdc.
c. Insulation Level 4.2 kV ac rms.
d. Creepage Distance 1.88 inch (min).
e. 60 Hz Withstand Voltage, Dry 35 kV.
f. 60 Hz Withstand Voltage, Wet 18 kV.

3. Use: Insulators shall be suitable for various assemblies including cantilevers, cross spans, headspans and for use as strain insulators.

4. Metal Parts: Malleable iron, or forged steel; galvanized prior to assembly in accordance with ASTM A153, or stainless steel.

5. Environment: Insulators shall be capable of withstanding service in an environment which includes exposure to:
   a. Ultraviolet radiation.
   b. Moisture.
   c. Surface discharges.
   d. Ozone.
   e. Temperature extremes.
   f. Engine exhaust fumes.
   g. Urban contaminants such as industrial pollutants.

6. Porcelain Insulators:
   a. Manufacture from best commercial-grade wet-process porcelain in accordance with ASTM D116.
   b. Glaze entire porcelain surface of insulator that will be exposed after assembly in Number 70 light gray color as specified in ANSI Z55.1.
   c. Insulator Surface: Free of imperfections.
   d. Cause for Rejection:
      1) Imperfections in glaze repaired by recoating and re-firing
      2) Imperfections in glaze repaired by retouching with paint.

7. Synthetic Insulators:
   b. Ultraviolet Protection: Integrated within molded casting material and not as an exterior coating applied to the surface.
c. Stress due to temperature variation and cyclical mechanical extension/contraction in any part of insulator under load and normal handling shall not lead to deterioration.

d. Chemical interactions shall not cause degradation of materials.

8. Strain and Suspension Insulators:

a. Mechanical strength shall exceed ultimate strength of conductor, wire or cross span guy to which it is attached.

b. Insulators shall be furnished complete with integral hardware suitable for connection to supports or contact hardware.

c. Fiberglass-reinforced epoxy solid rod type.

d. Rod fibers shall run longitudinally through the rod length.

e. End fitting attachment methods: Compression sleeve, wedge or adhesive. If adhesive is used, adhesive shall encapsulate rod in end-fitting cavity and shall form a compressive wedge upon loading.

f. End fittings attached to an insulator’s fiberglass rod shall ensure exact alignment with rod and assemblies connected to insulator in order to avoid torsional stress when insulator is installed.

9. Composite Type: Molded ethylene propylene copolymer jacket or weather sheds formed over a fiberglass-reinforced epoxy core. Interface between rod and weather shed shall, for life of the insulator, remain void free and dry without experiencing moisture ingress damage.

10. Each insulator shall bear the manufacturer’s name or trademark and year of manufacture, clearly and permanently imprinted, without affecting appearance or function of insulator.

2.04 WIRE AND CABLE

A. Stainless Steel Wire and Wire Rope:

1. Stainless steel wire and wire rope shall be used for the following applications:

2. Dead-ends, headspan and cross span wires.

3. Pull-off assemblies.

4. Bridle wires.

5. Cantilever top ties.

6. Head guys and down guys.

7. OCS assemblies.

8. Galvanized wire and wire rope shall not be used.

B. Contact Wire:

1. Solid grooved hard drawn copper, conforming to or exceeding requirements of ASTM B47.
2. Size: 350 kcmil.

3. Wire Reels:
   a. Wire shall be wound on reels, with wire vertical axis normal to barrel of the reel.
   b. Wire shall be wound evenly, tightly and with no kinks.

4. Diameter of the reel spindle shall be large enough to prevent wire twist when running wire off of the reel.

C. Messenger Wire:
   1. Hard drawn copper, ASTM Standard B8 and B1, class AA, bare.
   2. Size: 19-strand 500 kcmil.
   3. Wire Reels:
      a. Wire shall be wound evenly, tightly, and with no kinks.
   4. Diameter of the reel spindle shall be large enough to prevent wire twist when running wire off of the reel.

D. OCS Jumper Wire:
   1. In Span Jumpers: 350 kcmil stranded, annealed copper cable, ASTM B3 and B173, Class G or H, bare.
   2. Potential Equalizing Jumpers: 350 kcmil stranded, annealed copper cable; ASTM B3 and B173, Class G or H, bare.
   3. Full Current Jumpers: 350 kcmil stranded annealed copper cable; ASTM B3 and B173 Class G or H, bare.
   4. Insulated Feeder Jumpers:
   5. Feeder cable at each location shall be installed as shown on the Drawings. Insulated feeder cable requirements are specified in Section 34 21 28, Medium-Voltage Conductors and Cables.
   6. Surge Arrestor Ground Wire:
   7. Surge arrestor ground wires at each location shall be as shown on Drawings. Insulated cable requirements are specified in Section 34 21 28, Medium-Voltage Conductors and Cables.

2.05 DISCONNECT SWITCHES
   A. Refer to Section 34 23 27, Overhead Contact System Pole-Mounted Disconnect Switches.

2.06 SURGE ARRESTERS
   A. Refer to Section 34 21 16.22, TES - DC Surge Arresters.
2.07 OCS FITTINGS AND HARDWARE

A. OCS fittings and hardware shall include the following items, which combined with other major items, complete the Overhead Contact System.

1. Clevis fittings.
2. Clamps.
3. Nuts, bolts, lock washers and cotter pins.
4. Terminations.
5. Cross contact assembly.
6. Dead ends.
7. Turnbuckles.
8. Wire splices and connectors.
11. Links and eyebolts.
12. Hanger assemblies.
13. Thimbles and wire sleeves.
14. Miscellaneous hardware items.

B. Required Characteristics:

1. Reusable: Select fittings and hardware used for the various OCS assemblies that can be reused after removal.
2. Weather Resistant: Fittings and hardware shall not rust under climatic conditions experienced in the specific project location of western Washington State.
3. Easy Interface: Fittings and hardware shall be designed to allow an easy interface with other components of OCS system.
4. Dimensional Standard: Components shall be designed such that all fastenings and adjustments are accomplished with tools of one dimensional standard.
5. Fittings and hardware shall be designed and installed in a manner which will provide a homogenous OCS hardware and assembly arrangement.

2.08 METALS

A. Structural Steel Shapes and Plates: ASTM A36, ASTM A6, ASTM A572.
C. Hot-Rolled Steel Bars (including Bar-sized Shapes): ASTM A575 (Merchant Quality) or ASTM A576 (Special Quality), quality and grade as selected by fabricator as best suited for its use, and ASTM A29.
D. Cold-Finished Steel Bars: ASTM A108, grade as selected by fabricator as best suited for its use, and ASTM A29.

E. Steel Pipe: ASTM A53, Type E, F or S at fabricator's option, Grade A, black finish unless indicated in the Contract Documents as galvanized, or ASTM A500, or ASTM A1085.

F. Hot-Formed Rectangular Steel Tubing: ASTM A501, butt-welded, cold-finished and stress relieved, or ASTM A1085.

G. Gray Iron Castings: ASTM A48, Class 30B.

H. Malleable Iron Castings: ASTM A47, grade as selected by the fabricator as best suited for its use subject to approval by the Resident Engineer.

I. Steel Sheet for Cold-Forming: ASTM A1011, hot-rolled sheet steel of commercial quality, pickled and oiled and free of defects which would impair the work.

J. Stainless Steel Sheet Steel: ASTM A240.

K. Material for Galvanizing:
   1. Geometrically suitable for galvanizing as indicated in ASTM A384 and A385.
   2. Steel materials suitable for galvanizing include structural shapes, pipe, sheet, fabrications and assemblies.
   3. Chemically suitable for galvanizing.
   4. Zinc for Galvanizing: Conform to ASTM B6 as indicated in ASTM A123.

L. Galvanizing Repair: Galvalloy by Metalloy Products Co., Hardhat 2185 by Rust-oleum, or ZRC by ZRC Chemical Products, or approved equal.

2.09 FASTENERS AND ANCHORAGE MATERIALS

A. Refer to Section 34 23 25, OCS Anchorage to Concrete for concrete anchor details.

B. Items indicated below are for minimum general conditions:
   1. Bolts: ASTM A325 Grade A.
   4. Lag Bolts: FS FF-B-561, type and grade as required
   5. Washers: Carbon steel; plain, round complying with FS FF-W-92; locking, helical spring complying with FS FF-W-84.

2.10 FABRICATED METAL

A. All fabrication and erection of structural steel shall be performed in accordance with latest edition of AISC Manual of Steel Construction.

B. For the fabrication of metalwork which will be exposed to view, use only materials which are smooth and free of surface blemishes including pitting, seam marks, roller and grinding marks or welds. Remove marks by grinding, prior to cleaning, treating and application of finishes, including zinc coatings.
C. Use materials of the size and thickness indicated in the Contract Documents, or if not indicated, of the required sizes and thickness to produce strength and durability in the finished product consistent with the design. Work to the dimensions indicated in the Contract Documents or accepted on shop drawings, using proven details of fabrication and support. Use the type of materials indicated in the Contract Documents.

D. Form exposed work true to line and level with accurate angles and surfaces and straight sharp edges. Ease exposed edges to a radius of approximately 1/32 inch unless otherwise indicated in the Contract Documents. Form bent-metal corners to the smallest radius possible without causing grain separation or otherwise impairing the Work.

E. Verify dimensions by accurate field measurement before fabrication whenever work adjoins other Work that precedes it in construction. Do not delay job progress; allow for trimming and fitting of metalwork whenever the taking of field measurements before fabrication might delay the Work. On shop drawings, note which dimensions have been verified by field measurement.

F. Weld corners and seams continuously and in accordance with the recommendations of AWS D1.1. Grind exposed welds smooth and flush to match and blend with adjoining surfaces.

G. Form exposed connections with hairline joints which are flush and smooth, using concealed fasteners whenever possible. Use exposed fasteners of the type indicated in the Contract Documents, and if not indicated, use stainless steel Phillips flat-head (countersunk) screws or bolts.

H. Pre-drill bolt and screw holes as indicated in the Contract Documents and as required for attachment of metalwork and for the attachment of adjacent materials.

I. Cut, reinforce, drill and tap metalwork as required to receive finish hardware and similar items of work.

J. Use hot-rolled steel bar for work fabricated from bar stock, unless work is indicated in the Contract Documents or to be fabricated from cold-finished or cold-rolled stock.

K. Preassemble work at shop to the greatest extent possible to minimize field splicing assembly of units at the Worksite. Disassemble units to the extent necessary to comply with shipping limitations. Mark all units clearly for assembly and proper installation.

L. Where indicated as galvanized, complete the shop fabrication prior to application of the coating. Remove mill scale and rust, clean and pickle the units as required for coating. Apply hot-dip zinc coating of two ounces per square foot in accordance with ASTM A123.

M. Castings:
   1. Strength and selection of grade to satisfy loading requirements.
   2. All castings to be clean and free of pitting and fissure impurities.
   3. Clean and/or grind irregularities before galvanizing.

N. Metal Plates:
   1. Fabricate metal plates in accordance with ASTM A36, ASTM A6, and ASTM A572. Catenary ground plates to be fabricated as indicated in the Contract Documents.
2.11 FINISHES - GALVANIZING

A. Steel members, fabrication and assemblies to be galvanized after fabrication.
   1. Method: Hot-dip process in accordance with ASTM A123.
   2. Weight of zinc coating to conform to requirements indicated under ASTM A123, Weight of Coating, unless otherwise directed by the Resident Engineer.

B. Safeguard against steel embrittlement in conformance with ASTM A143.

C. Safeguard against warpage or distortion of steel members shall conform to ASTM A384. Notify the Resident Engineer of potential warpage problems which may require modification in design before proceeding with steel fabrications.

D. Finish and uniformity of zinc coating and adherence of coating to conform to ASTM A153.

E. Apply passivating treatment or light oiling to prevent humid storage stain to galvanizing materials subject to extended periods of storage in open exterior locations. Treatment, solution and process to be subject to the Resident Engineer’s approval.

F. Do not treat freshly galvanized or passivated surfaces with oils, grease, or chemicals which might interfere with adhesions of subsequent paint primers and coatings.

G. Visually inspect galvanized materials, fabrications and assemblies for conformity with applicable requirements of AHDGA, Inspection Manual for Hot-Dip Galvanized Products. Submit inspection reports to the Resident Engineer.

H. Galvanizing to be performed by a company belonging to the American Galvanizers Association.

PART 3 - EXECUTION

3.01 INSTALLATION - GENERAL REQUIREMENTS

A. The following describes the work required for the installation of the wiring and fittings of the complete OCS system.

B. Work shall also include design verification, stringing, tensioning, supporting and registering the conductors, jumpers, feeders, surge arrestors and other ancillary equipment and hardware, including contact bridges and other components, as required to provide a complete and fully operational OCS.

C. Contractor shall be responsible for coordinating the OCS installation. Contractor shall also submit, for review and approval by the Resident Engineer, drawings for temporary anchorages, guying and electrical isolations.

D. The manufacturer’s recommended installation practice shall be followed. Information in these specifications shall be incorporated and accounted for by the manufacturer’s recommended installation practices. All installation shall be in accordance with the requirements in these Specifications and State and local regulations.

1. Verify along track stationing and structure offsets of pole foundations, concrete inserts, and concrete embedded framing channels prior to commencing Work. Notify the Resident Engineer within 2 days of finding any discrepancies.

2. New or existing components shall not be drilled, cut, bent or reamed without prior approval of the Resident Engineer.
E. Fasteners shall include bolts, nuts, locknuts, washers, pins, turnbuckles, machine screws and other items that may be used to attach items together.

1. Fasteners shall be installed in accordance with the manufacturer's recommendations.

2. Bolts shall be of sufficient length to allow two full threads to extend beyond the nuts and locknuts; however, the end of the bolt shall never extend more than 1.5 inches beyond the nut or locknut.

3. Threads of bolts, nuts, and machine screws shall be lightly lubricated prior to assembly, and shall be torqued using a calibrated torque wrench in accordance with the manufacturer recommendations.

4. Fittings, fasteners, or any other attachments that do not fit, are cracked, sustain galvanizing damage during installation, or are found to be defective in any way shall be rejected.

F. Turnbuckles, where used, shall be installed in a manner which will provide 6 inch adjustments in each direction for future maintenance. Final installation shall provide adjustment in both directions for future maintenance.

G. At each stage of work, contact wire shall be handled with specific care to avoid bending, kinking, twisting, or other forms of damage. Damaged contact wire shall be replaced with new contact wire by the Contractor. Kinked contact wire shall be straightened by the Contractor.

H. Contractor is responsible for proper fit of OCS pole bases and downguy anchor plates to foundation anchor bolts.

I. Anchor securely as indicated in the Contract Documents or as required for the intended use.

J. Install insulating devices or butyl tapes in between dissimilar metals.

K. Installation Tolerances:

1. The installed OCS shall conform to the dimensional requirements shown on the Contract Drawings within the following tolerances:
   a. Contact wire height in tunnels: -0 inch, +1/2 inch.
   b. Contact wire height in open route: -0 inch, +1 inch.
   c. Contact wire height in stations: -0 inch, +1 inch.
   d. Contact wire stagger at registration: +/- 1/2 inch.
   e. System height: 1 inch.
   f. Hanger location: 3 inches.
   g. Hanger length: 1/4 inch.
   h. Messenger to contact wire lateral displacement at support: 1 inch.
   i. Pole base elevation: 1 inch.
   j. Pole rake (after loading): 1 inch (at top).
k. Wire tension: 50 pounds.

3.02 OCS CONDUCTOR STRINGING

A. Overhead conductors shall be installed in accordance with the Contractor's Construction Work Plan (CWP), as approved by the Resident Engineer.

B. Allowance shall be made for conductor creep:

1. In order to reduce creep, the Contractor shall pre-stress the contact wires prior to final installation. The procedure for pre-stressing the contact wire shall be submitted to the Resident Engineer for approval. CWP shall describe the proposed method including:

   a. The pre-stress tension for the contact wire before being reduced to normal tension.

   b. The duration the conductor shall remain at the pre-stressed tension as defined in the contractor's construction work plan.

   c. The Contractor's check of the adequacy of the catenary structures to ensure that they can safely carry any proposed loading in excess of the design values.

C. Conductor Erection Spreadsheet:


2. Prior to setting conductor tension, measure actual conductor temperature using contact thermometer.

3. Enter conductor temperature and span data on the Conductor Erection Spreadsheet and use to ensure conformity to actual wire data before starting contact wire final stringing.

4. Update Conductor Erection Spreadsheet for each section of wire.

D. Conductors:

1. Attach to anchor and string out, holding conductors in its approximate lateral and vertical position in relation to the track centerline.

2. Prevent kinking by using temporary rollers at supports and approved pulling and clamping devices.

3. Pre-stress conductors after stringing.

4. After pre-stressing conductors, reduce to installation tension appropriate for the conductor temperature and attach to cantilever insulators or steady arms, removing twists in contact wire by working from one anchor to the other.

E. After final tensioning has been completed, the headspans, cross spans, cantilevers and pull-offs shall be checked and the conductor heights, staggers, heel settings and along track position adjusted as required in order to obtain the values given in Contract layout drawings.
3.03 ASSEMBLY INSTALLATION

1. Down Guy Anchor Plates:
   a. Install in a similar fashion as pole baseplates, in accordance with specification Section 34 23 13, Overhead Contact System Metal Poles.

2. Support Assemblies, Drop Pipes, and Drop Vertical Supports:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.
   b. Shall be plumb, within 5 degrees.

3. Fasteners, Eyebolts and Anchor Bolts:
   a. Fasteners shall include bolts, nuts, locknuts, washers, pins, turnbuckles, machine screws and other items which may be used to attach items together.
      1) Fasteners shall be in English units unless otherwise approved by the Resident Engineer.
      2) Fasteners shall be installed in accordance with the manufacturer’s recommendations.
      3) Field connection shall be bolted unless otherwise noted in Contract Documents.
   b. Bolts:
      1) Bolt holes: Minimum size 1/16 inch larger than bolt diameter, unless otherwise noted in Contract Documents.
      2) Bolt length:
         a) Bolts shall be of sufficient length to allow two full threads to extend beyond the nuts and locknuts
         b) End of bolt shall never extend more than 1.5 inches beyond nut or locknut.
      3) Bolt and Nut Installation:
         a) Lubricate lightly threads of bolts, nuts, and machine screws prior to installation.
         b) Torque bolts using a calibrated torque wrench in accordance with manufacturer’s recommendation.
      4) Defective fittings shall not be used:
         a) Fasteners that do not fit.
         b) Cracked fasteners.
         c) Fasteners with galvanizing damaged during installation.
         d) Fasteners found to be defective in any other way.
c. Provide anchor bolts where indicated on Contract Drawings.
d. Fittings shall not use epoxy inserts as a method of attachment.
e. Anchor Bolts:
   1) Install in accordance with Section 34 23 25, Overhead Contact System Anchorage to Concrete.

4. Cantilevers:
   a. Assembly of cantilevers:
      1) Suitable fixture to allow pre-assembly of the cantilevers, to specific dimensions, shall be developed.
      2) Use the fixture together with wire heights, staggers given in the layout plans and the actual pole to track centerline site dimension, at contact wire level to manufacture the cantilever for each location.
      3) Contractor shall prepare diagrams or charts indicating the actual cantilever tube lengths and diameters for each cantilever installed throughout the project.
      4) The documents, in addition to the tube lengths, shall also indicate the cantilever location, track and OCS registered and supported.
   b. Erecting Cantilevers:
      1) Contractor shall erect the cantilevers on each pole at the heights necessary to obtain the designed OCS heights.
      2) For stability during conductor stringing, the Contractor shall temporarily restrain the cantilever in the along track direction to prevent collapse.
      3) Conductors shall not be clipped in to the arm until after pre-tensioning is completed.
   c. Cantilever Fittings:
      1) Cotter pins and nuts on each cantilever shall be located on the side of the structure facing normal direction of traffic.
      2) In addition, the assemblies fitted with these components shall be oriented, whenever possible, in a manner which will hold the components together by gravity and radial load should the pins or nuts become detached during service conditions.
      3) Shall be installed in the proper direction as depicted on the approved shop drawing.
   d. Components employing a hinge or swivel shall be greased with approved grease before assembly of the rubbing surfaces and cleaned of excess grease.
e. After installation of the cantilevers and stringing of the conductors, adjustments shall be made to the stagger, heel setting, contact wire heights and alignment as necessary. All cantilevers shall be held perpendicular to the track for a wire temperature of 60 degrees F, and the wire shall be tensioned to the design tension derived from the Erection Tension Charts in the Contract Drawings. Contractor may submit alternative method to the Resident Engineer for approval.

5. Head Spans:
   a. Cross spans, headspans, and bridle assemblies shall be manufactured in accordance with the OCS layout drawings.
   b. Assemble cross spans, headspans, and bridles after each installation location has been surveyed and the following necessary information and dimensions measured along the axis of the span have been checked:
      1) Face of station wall to face of wall.
      2) Design centerline of track to face of station wall.
      3) Design centerline of track to centerline of track.
      4) Elevation of the foundations in relationship to the tracks.
      5) Track superelevations and direction.
   c. Provide cross span and headspan insulation in addition to inter-track insulation that may be required.
   d. Design cross spans to clear pantograph dynamic envelope shown on Contract Drawings.
   e. The loading on each assembly shall be checked to ensure that each assembly is acceptable under each loading condition, shall not sag and shall not infringe on the pantograph clearance envelope.

6. Cross spans:
   a. See Head Spans Above.

7. Span Wire and Portal Registrations:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.

8. Pull offs:
   a. Pull-off assemblies shall be manufactured in accordance with the approved Contractor’s OCS layout drawings.
   b. Actual site measurements for each pull off shall be obtained prior to pull-off assembly installation on the poles.
   c. After conductor stringing, pull-offs shall be adjusted to obtain the correct conductor heights, staggers and heel settings.
d. The loading on pull off assemblies shall be checked to ensure that each assembly is acceptable under all loading conditions, shall not sag and shall not infringe on the pantograph clearance envelope.

9. Tunnel Supports:
   a. At each location where a tunnel support or bridge attachment shall be installed, verify all field measurements prior to installation
   b. After installation of tunnel support or bridge attachment the contractor shall verify that all required clearances are met.
   c. Adjust tunnel arms to obtain conductor heights and staggers as shown on Contractor's layout plans after assembly installation.
      1) Adjust the contact support arm to ensure that the uplift, under normal pantograph pressure, does not exceed the value used in the pantograph clearance envelope.
      2) Leave sufficient adjustment of the assembly available to allow for future maintenance requirements.
      3) Carefully check each location to ensure that the electrical clearances between live equipment and the tunnel or live equipment and the pantograph envelope are not infringed under any climatic conditions.

10. Section Insulators:
   a. Cut section insulators into tension length only after OCS is at final tension and adjustments have been made and final checking completed.
   b. Section insulator types and locations shall be as shown on the Contract layout drawings and shall be installed in accordance with the manufacturer's recommendations.
   c. The section insulator shall be adjusted to provide a smooth passage for the pantograph without causing rocking or excessive arcing.
   d. The section insulator shall be free to move along track without twisting or becoming misaligned.
   e. Electrical connectors and clamps shall be prepared and protected externally and internally in accordance with the manufacturer's recommendations.
   f. Extreme care shall be taken during installation of the section insulator to ensure that the conductors are not damaged. Damaged contact wire or section insulator shall be replaced at the Contractor's expense.

11. Feeder Connections:
   a. Connect dc feeder cables where shown on Contractor's OCS layout drawings and install as indicated on Contract Drawings.
   b. Install, secure, and shape the feeder cables to avoid conflicts with pantograph.
c. Connect feeder jumpers to supports, cross spans and headspans by means of insulated cable straps.

d. Clean, wire brush, and lubricate conductor with manufacturer-recommended conductive grease before installing connector clamps to contact wire.

e. Verify that when tightened to manufacturer’s recommended torque value no distortion occurs to the feeder wire, messenger wire, or contact wire.

12. Balance Weights:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.
   b. Yoke plate shall be plumb, within 5 degrees.

13. Fixed Anchors:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.

14. Y-Terminations:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.

15. Spring Terminations:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.

16. Knuckles:
   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.

17. Contact Bridges:
   a. Contact bridges shall use shop straightened contact wire and shall be installed at turnout locations shown on Contractor’s layout drawings.
   b. The contact bridges shall allow free movement of the contact wires over the operating temperature range.
   c. Adjust upper contact wire to float through the contact bridge assembly under normal conditions with no pantograph uplift.

18. Jumpers:
   a. Jumpers and feeder cables shall be erected where shown on the OCS layout drawings and shall be installed as indicated.
   b. Calculate the required lengths of the jumpers, based on actual field measurements and the jumpers shall be installed to avoid conflicts with the pantograph, adjacent cantilevers and contact wire bridges.
   c. Install connection clamps in accordance with manufacturer’s recommendations.
d. Clean, wire brush, and lubricate conductor with manufacturer-recommended conductive grease before installing connector clamps.

e. Maximum wire projection through connection clamp: 1/2 inch.

f. Tie wire-ends.

g. The connector bolts shall be torqued to the manufacturer's recommendations using a calibrated torque wrench.

19. **In-Span Insulators:**

   a. Insulators shall be cleaned before installation.

   b. Only clean rags free from abrasive material shall be used for cleaning insulators.

   c. Wire brushes shall not be used for cleaning parts of an insulator including the metal fittings.

   d. In each completed line section, insulator assemblies shall be clean, bright and free from nicks, chips or other marks. Porcelain insulators having broken or cracked sheds or porcelain coating shall be rejected and replaced with new insulators.

   e. Where runnable type in-span contact wire insulators are used the transition between the runnable insulator and the contact wires shall be smooth and arc-free during operation.

20. **Splices:**

   a. Conductor splicing is necessary at the locations shown on the contract drawings.

   b. Conductor splicing is necessary at the South end of the Northgate Link Extension work to tie-in with UW Station, where conductors are terminated from a previous contract.

   c. No other contact and messenger wire splices are permitted without prior approval of the Resident Engineer.

   d. Contact wire ends shall be cut straight to allow for flush mating in the contact wire splice. There shall be no gaps between running surfaces of the contact wire. After installation of contact wire splice, the running surface of the contact wire shall be filed smooth to provide a smooth, arc-free transition between the spliced contact wires.

21. **Midpoint Anchors:**

   a. Install in accordance with Contract Drawings and manufacturer’s recommendations.

22. **Bridles:**

   a. See Head Spans above.

23. **Downguys and Headguys:**
a. Pole attachments may be erected and adjusted as required during the pole erection process.
b. Installation shall be based on the approved OCS layout plans and the Contractor's subsequent designs of down guys.

24. Hangers:
   a. Install in accordance with Contract Drawings and manufacturer's recommendations.
   b. Messenger wire clips shall be straight up and down after final installation.
   c. Contact wire clips shall be straight up and down after final installation.
   d. Hanger wire shall be straight up and down after final installation.

25. Brackets, Pole Bands and Pole Slings:
   a. Install in accordance with Contract Drawings and manufacturer's recommendations.

26. Anchor Brackets:
   a. Install in accordance with Contract Drawings and manufacturer's recommendations.

27. OCS Monitoring System:
   a. The Contractor shall run power and communications cables between the OCS Monitoring System, the communications interface cabinet and the communications cases. Power and communications cables shall be separated if installed in the same raceway.
   b. Install in accordance with Contract Drawings and manufacturer's recommendations.

28. Warning Signs and attachment method:
   a. Pole Identification Sign:
      1) Shall be installed as shown in the Contract Drawings.
   b. Live Wire Warning Sign:
      1) Shall be installed on poles adjacent to overhead bridges
      2) Shall be installed on both sides of the pole facing the track
      3) Shall be installed at 15' above top of rail.
   c. Warning Sign for Station Platform:
      1) Shall be facing both tracks on each pole inside the station limits.
   d. Pole ID Label:
      1) Shall be installed as shown in the Contract Drawings.
   e. Warning Sign, End of Electrification:
1) Shall be installed on the pole at the end of the alignment facing oncoming vehicles.

f. Warning Sign for Grade Crossing:

1) Shall be installed facing both tracks on poles adjacent to grade crossings.

g. Identification signs shall be applied after painting of the mounting surface.

h. Ensure that surfaces where signs are attached are free of ice, dirt, or foreign objects.

i. Install other signs as shown on Contract Documents in type and locations as indicated.

29. Miscellaneous:

a. Install the underground feeder cables from the disconnect switches to the substations, as indicated, and feeder cables and jumpers from the disconnect switches to the OCS as depicted in the Contract Drawings.

3.04 GROUNDING

A. Refer to Section 26 05 26, Grounding and Bonding, for grounding specifications.

B. On each pole without a surge arrester, a 4/0 pole ground wire shall be exothermically welded to the top of the existing foundation ground rod or existing exposed ground tail.

C. On each pole requiring a surge arrester that is installed on a drilled – cast in place foundation drive a ground rod in accordance with Section 26 05 26, Grounding and Bonding and connect the ground side of the arrester to the ground rod with a 2.4 kv rated flexible 4/0 conductor as shown in the Contract Drawings.

D. The final connection of the 4/0 ground wire to each OCS pole shall be made with a crimped lug bolted to the stud provided by the pole manufacturer inside the pole.

E. Where exothermic welds are to be made to a galvanized surface, galvanizing shall be removed using a grinding wheel to expose a clean surface.

F. After welding, repair the galvanized coating on the steel surface as required in this specification.

G. Exothermic welding cartridges and molds shall be for the type of weld shown on the Contract Drawings and be performed in accordance with the manufacturer’s recommendations. Worn and damaged molds shall not be used. Where directed by the Resident Engineer, welds and molds shall be replaced.

3.05 FIELD QUALITY CONTROL

A. Inspections and Tests:

1. Inspection, tests and samples to conform with listed ASTM Specifications and Standards.

2. Inspection rights and privileges, procedures and acceptance or rejection of galvanized steel materials to conform to ASTM A123.
3. Inspection and tests submitted to the Resident Engineer to include the following:
   a. Visual examination of samples and finished products.
   b. Tests to determine weight or mass of zinc coating per square foot of steel surface.
   c. Tests to determine distribution and uniformity of zinc coating.
   d. Test to determine fissures and voids in castings. Submit minimum of one of each type casting for dissecting to the Resident Engineer with each new casting lot. Results of testing are cause for rejecting casting and/or lot. Decision of the Resident Engineer is final.

4. Tests to determine thread fittings of units, washers to bolts.

B. Shop Welding Inspection and Testing:
   1. Visual Inspection: AWS D1.1. Visually inspect 100 percent of welds on both permanent and temporary work.
   2. Ultrasonic Testing: AWS D1.1. Test complete joint penetration groove welds as follows:
      a. 10 percent with thickness equal to or less than 3/4 inch.
      b. 50 percent with thickness greater than 3/4 inch and equal to or less than 1-1/2 inches.
      c. 100 percent for thickness greater than 1-1/2 inches.
   3. Magnetic Particle Inspection: AWS D1.1. Inspect complete and partial joint penetration groove welds and fillet welds as follows:
      a. 20 percent of complete joint penetration groove welds of tee and corner joints.
      b. 10 percent of partial joint penetration groove welds and fillet welds.
   4. Liquid Penetrant Inspection: AWS D1.1. Liquid penetrant inspection may be used for detecting discontinuities that are open to the surface.
   5. Radiographic Testing: AWS D1.1 as requested by the Resident Engineer.

C. Shop Bolting Inspection: Visually inspect 100 percent of shop bolted connections.

D. Shop Inspection and Testing by the Resident Engineer:
   1. Allow the Resident Engineer access to perform independent verification testing and inspection.

E. Welds and bolted connections are subject to inspections and tests by the Resident Engineer. The Resident Engineer will select inspect welds at random.

3.06 REPAIR

A. Report damage to the Resident Engineer and provide a reason for damage to the equipment.
1. Provide a proposed repair procedure or remove and replace damaged components.

2. No repairs of insulators shall be allowed, replace damaged insulators prior to turn over of system.

3. Damaged parts that have been replaced shall be removed from the site.

4. Make repairs to the OCS only as approved by the Resident Engineer.

B. Contact Wire Repair:
   1. Vertical and Lateral Kinks:
      a. Remove kinks using a leather, copper faced hammer, hydraulic actuated crimping tool, roller, or other method/tool approved by the Resident Engineer.
      b. Beat the contact wire with the special hammer against a flat smooth surface such as a hardwood block.
   2. Correct twists in the contact wire.
   3. The Resident Engineer will determine whether contact wire repair is satisfactory.
   4. Replace contact wire that cannot be repaired to the satisfaction of the Resident Engineer.

C. Galvanizing Repair:
   1. Damage to the galvanizing of pipes, drop tubes, brackets and steady arms shall be repaired by the brush application of a specified suitable zinc-rich, cold galvanizing repair paint, ZRC Cold Galvanizing Compound, or an approved equal.
   2. Spray application is not permitted.
   3. Surface preparation and application of the galvanizing repair shall be in accordance with the repair material manufacturer's recommendations.
   4. Other components with damaged or defective galvanizing shall not be installed and shall be removed from the construction site.
   5. Work associated with galvanizing repair will be at Contractor's expense.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. Section includes:
      1. OCS pole-mounted, manual, no load break DC disconnect and DC bypass switches.

1.02 REFERENCES
   A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.
      1. ASTM International (ASTM):
      2. Institute of Electrical and Electronics Engineers (IEEE):
      3. National Electrical Manufacturers Association (NEMA):
         a. NEMA 250 - Enclosures for Electrical Equipment (1,000 Volts Maximum).
         b. NEMA ICS 1 - Industrial Control and Systems: General Requirements.
         c. NEMA ICS 2 - Industrial Control and Systems Controllers, Contactors and Overload Relays Rated 600 Volts.

1.03 SUBMITTALS
   A. Submit:
      1. Product Data: Complete manufacturer's descriptions, catalog data, and information including materials and model numbers.
      2. Shop Drawings: Manufacturer's general and detail arrangement drawings for components comprising switch assembly.
         a. Show all dimensions including mounting and operating handle.
         b. Parts list, illustrations and diagram for components.
         c. Interlock data.
      3. Operation and Maintenance Data:
         a. Description of the switch, its components and interlock.
PART 2 - PRODUCTS

2.01 DC DISCONNECTING SWITCHES

A. Description: The DC disconnecting switches shall be single-pole single-throw, or single-pole double-throw air break switch type with manual operator mechanism for operating at track level.

1. Design shall comply with the applicable requirements given in IEEE C37.34, ASTM B187/B187M, NEMA ICS 1, and NEMA ICS 2.

2. Ratings:
   a. Voltage: 1500 Vdc.
   b. Insulation Level: Dry 1 minute power frequency 5.7kV rms (energized parts to ground and gap between positive and negative parts).
   c. Continuous Current Ratings: As noted on Contract Drawings. Rating to be applied without the switch contact temperature rise exceeding 50 degrees C above a maximum ambient temperature of 40 degrees C.
   d. Momentary Peak Current Withstand: Not less than 90 kA.
   e. Short-Time Current Rating: Not less than 70 kA, average, for 0.25 second.

B. Switch Insulation Structure: Materials used for the switch assembly insulation structure shall be noncombustible, nonhygroscopic, and tracking resistant. The mechanical strength of the insulation structure shall match the stresses imposed by the rated momentary current.

C. Switch Contacts:

1. Moving and stationary contact surfaces shall be silver-plated copper. All other current-carrying parts shall be of high-conductivity copper or copper alloy. Contacts shall be self-aligning, wear compensating, and with initial wiping action.

2. Hinge and jaw contacts shall be bolted-pressure type with non-ferrous or stainless steel self-clamping mechanism, or other approved high-pressure type contact arrangement.

D. Pole-Mounted Manual-Operated Disconnecting Switch Assembly:

1. Disconnect switches shall be single or twin, two-position, single-throw, non-load-break, non-grounding (except where indicated otherwise), non-fusible air switches with arcing horns. Basis of Design: MAC Products, Inc. D-16452 or approved equal.

   a. Disconnect switches shall be capable of breaking load currents under emergency conditions.
b. Switches shall be suitable for mounting on tapered-tubular, or wide-flange poles.

2. Disconnect switches shall be equipped with a pole-mounted operating tube, links and a handle for operating at track level, insulated from the switch.

3. Operating mechanism:
   a. Operating mechanism shall operate easily, without free movement.
   b. Provide operating handle with heavy-duty lugs to accept one padlock, provided by Contractor, in the fully open or closed switch positions. Resident Engineer to provide padlock keying requirements.
   c. The manual operating mechanism of the pole mounted switches shall not intrude into the vehicle envelope.

4. Provide corrosion resistant nameplates permanently secured to enclosure to show OPEN and CLOSED positions of switch contacts.

5. Disconnect switch blades and contact surfaces shall be silver-coated copper or copper alloy.

6. Provide for SCADA indication of the operating handle position. Provide conduit, devices and wiring and a pole mounted junction box with open and closed contacts and terminal strip for SCADA connection.

E. Interlocking device: Provide keyed interlock systems were shown on Contract documents to ensure that a pre-determined sequence of operation is followed to operate switches. Removal of a key will make the interlocked device non-operable mechanically and electrically. The same key shall enable operating the next interlock in the sequence. The interlock components shall be manufactured from electropolished 316 stainless.

F. Cable Termination: Provide line and load side disconnecting switch terminals with silver-plated copper bus complying with ASTM B187/B187M to accommodate the number and size of DC power copper cables, entering from below or from above, as indicated.

G. Provide switch terminals with the proper size and quantity of NEMA terminal lugs.

H. Perform tests in accordance with Section 34 23 69, Overhead Contact System Testing.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install disconnect switches at locations shown on Contract Drawings.

B. Install switches in accordance with approved manufacturer's instructions. Provide mounting hardware as required.

C. Coordinate installation with design of disconnect switch supporting hardware, feeder wire installation, and routing, and ensure designs are fully integrated with the installed attachments.

D. Attach operating mechanism of pole mounted switches and pole mounted junction box to poles and position so that handles do not intrude into the track clearance envelope.

1. In general, operating handle shall move away from or parallel to track.
2. Install switch such that a person operating the switch will not be in danger from passing vehicles.

3. If doubt exists about which way to face a disconnect switch, obtain clarification from Resident Engineer.

E. Install operating handle at a height that allows switch to be operated easily by a person standing on the ground.

F. Adjust switches after installation to provide proper mating of the blades and easy alignment and operation.

G. Provide cable clamps on line and load side of switches to prevent stress on connectors and switch jaws.

H. Perform tests in accordance with Section 34 23 69, Overhead Contact System Testing.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. The tests to verify compliance with Contract performance, reliability and maintainability requirements.
   a. Tests described in this Section shall be performed as indicated. Tests shall be performed on production components without modification or special preparation.
   b. The tests specified herein are considered to be an absolute minimum. The Contractor shall be responsible for assuring that each design and performance requirement of this Specification is assigned to a specific test effort. The Contractor shall submit a Test Plan as specified. The Contractor and its subcontractors may perform additional testing, as they deem necessary.
   c. Material test requirements may also appear in other Sections. Other test requirements may appear in other Sections. The Contractor shall integrate all of these tests into the Test Plan.
   d. After the OCS has been installed and ready for operation, Field Installation Tests and Field System Tests shall be performed to verify physical and electrical integrity of the system and to verify quality of workmanship.
   e. Following completion of field testing, Systems Integrated Tests shall be performed to demonstrate clearances and commutation without arcing.
   f. Testing equipment and personnel shall be provided by Contractor unless stated otherwise in these Technical Specifications.
   g. Contractor is responsible for performing all tests with qualified personnel.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. American National Standards Institute (ANSI)
   a. ANSI/NEMA C29 - Test Methods for Electrical Power Insulators
2. International Electrical Testing Association (NETA)
3. ASTM International (ASTM)
   a. ASTM B47 – Standard Specification for Copper Trolley Wire
b. ASTM A938 – Standard Test Method for Torsion Testing of Wire

1.03 SUBMITTALS

A. Submit:

1. Test and Evaluation Reports:
   a. Test Plan.
      1) Submit a comprehensive test plan and schedule. Provide monthly updates.
   b. Test Procedures.
      1) Each test listed in this specification requires a test procedure to be submitted for approval.
      2) Submit before test is scheduled to be performed.
      3) Submit for each test to be performed under the appropriate Technical Section of these Specifications, not under this Section.
   c. Test Results:
      1) Submit for each test to be performed under the appropriate Technical Section of these Specifications, not under this Section.
   d. Test Reports:
      1) Submit for each test performed under the appropriate Technical Section of these Specifications, not under this Section.
      2) Factory Design Test Reports:
         i) Existing test reports.
         ii) New test reports.
      3) Factory Production Test Reports:
         i) Existing test reports.
         ii) New test reports.
      4) OCS Field Acceptance Test Reports.
      5) System Integration Test Reports.
   e. Verification OCS is installed to specifications prior to field acceptance tests, signed by OCS Supervisor and Project Manager.

1.04 QUALITY ASSURANCE

A. Witnessing of Tests:

1. The Resident Engineer will, at his/her option, witness all tests.
2. Testing Notification: At least 30 days prior to each test upon the approval of test procedure, notify the Resident Engineer in writing of the date, time, and location the test will be performed.
3. If the Resident Engineer elects not to witness a test or tests, test reports shall nevertheless be submitted to Sound Transit for review and approval.

4. Witnessing of test by Resident Engineer shall not relieve Contractor from its responsibility to produce test report in accordance with Contract Documents.

B. Performance of Testing:

1. OCS system and its components shall be tested to verify compliance with Contract performance, reliability, and maintainability requirements.

2. Tests described in this Section shall be performed as indicated unless specifically waived by the Resident Engineer. Tests shall be performed on production components without modification or special preparation.

3. After the OCS has been installed and is to be made ready for operation, field installation and system testing shall be performed to verify physical and electrical integrity of the system and to verify quality of workmanship.

4. Factory design or production testing of individual components shall be performed by component manufacturer at the plant of manufacture or at a testing facility as approved by the Resident Engineer.

5. Field testing of insulated power cables rated 2 kV and higher shall be performed by a NETA certified technician working for an independent testing company under direct supervision of manufacturer of the substation equipment and hired by manufacturer of substation equipment.
   a. NETA technician shall have at least 5 years of experience in construction acceptance testing of similar equipment.
   b. Testing company shall be a NETA member. Evidence of qualification shall be submitted.
   c. After Resident Engineer approval, testing company shall not be discharged or otherwise replaced without written approval of Sound Transit.

6. Following completion of field installation and system testing, LRV tests shall be performed to demonstrate clearances and commutation without arcing.

C. Test Classifications:

1. Factory Design Tests (Level 1 tests):
   a. Shall be conducted by or under supervision of the equipment manufacturer.
   b. Shall demonstrate compliance with specified design requirements.
   c. Shall be performed on production components, assemblies, subsystems and substations and shall be performed on the highest level of assembly that will allow demonstration of design compliance.
   d. Limited to the number of units needed to demonstrate design compliance, typically one or two.

2. Factory Production Tests (Level 1 tests):
a. Shall be conducted by or under the supervision of the equipment manufacturer.

b. Shall demonstrate that the units to be delivered operate within specified limits and are in compliance with design requirements and industry standards.

c. Test requirements may vary from an inspection and functional demonstration for a simple component to a full system functional demonstration of an assembly.

d. Perform at OCS manufacturer’s facility prior to shipment of OCS equipment to the field.

e. Perform at ambient conditions unless a specific environmental or operating limit is necessary to demonstrate acceptable operation.

3. Field Installation Tests (Level 1 tests): Demonstrate that installed OCS over each track section is installed properly. Tests include:

a. Acceptance Measurements.

b. Mechanical Tests.

c. Clearance Tests.

4. Field System Tests (Level 2 tests): Demonstrate that installed OCS over each track section is ready for LRV testing functionally and revenue service cosmetically. Tests include:

a. Electrical Test.

b. OCS Energization Test.

5. Systems Integrated Tests (Level 3 tests):

a. Perform LRV tests with a Sound Transit LRV equipped for testing by Contractor as described below.

b. Demonstrate clearances to pantograph and LRV body.

c. Demonstrate operation at maximum permissible speed without loss of contact, arcing, or physical interference with a pantograph by the OCS.

d. Demonstrate other parameters the Resident Engineer considers important for efficient operation.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Supply tools and equipment for performance of tests with exception of LRVs and LRV operators which Sound Transit will furnish for the integrated testing.

2.02 SOURCE QUALITY CONTROL

A. Factory Design Tests:
1. Component Design Tests: Perform on each component specified in this Section and submit to Sound Transit for approval.
   a. Perform tests on first production units in accordance with these Specifications.
   b. If manufacturer of equipment has already performed design tests, existing test reports may be submitted to the Resident Engineer for approval.
   c. Existing test reports will not be required to meet format requirements specified in this Section.
   d. Existing test reports shall include relevant information.

2. OCS Insulators: Perform the following design tests as described in ANSI C29 for one insulator of each type and rating supplied:
   a. Power Frequency Withstand.
   b. Impulse Withstand.
   c. Thermal Capacity.
   d. Mechanical Strength.
   e. Resistance.

3. OCS Section Insulators: Perform the following design tests for one section insulator of each type supplied.
   a. Resistance to ultraviolet radiation and electrical tracking of insulating material.
   b. Mechanical strength.
   c. Electrical tests.

4. Poles: Contractor shall demonstrate acceptable deflection values of each type of pole procured under this Contract to the Resident Engineer.
   a. The demonstration shall be in the form of a factory design test, performed at the place of the manufacturer.
   b. The testing shall be non-destructive and at a place and time agreed by the Resident Engineer.
   c. Parameters to be tested include load at maximum deflection and deflection at 30 percent, 50 percent and 70 percent maximum design loading and extrapolating the results to 100 percent.
   d. The Contractor shall submit to the Resident Engineer, in writing, a test procedure for approval, prior to testing any poles.
   e. The test procedure shall include method of application of loads, recording devices, calibration of devices and other information deemed pertinent by the Resident Engineer.
   f. The test shall be conducted on a rigid foundation that resists translation and rotation in each axis.
B. Factory Production Tests - Components: Perform on each component specified in this Section and submit to Sound Transit for approval.

1. Fittings, Hardware and Cantilever Tubes: Perform following production tests in accordance with ASTM standards:
   a. Chemical analysis tests on each lot. A lot shall consist of castings produced by one furnace melt.
   b. Sample galvanizing tests upon completion of fabrication.
   c. Visual and dimensional tests upon completion of fabrication.
   d. Tests to determine thread fittings of units, washers to bolts.

2. Stainless Steel Wire and Wire Rope.
   a. Test stainless steel wire and wire rope used as support wires and pull-offs in accordance with ASTM A368, ASTM A492 and ASTM A555.

3. Section Insulators:
   a. Perform following tests in accordance with applicable Standards:
      1) Dry flashover tests.
      2) Wet flashover tests.
      3) Low frequency dry withstand test.
      4) Low frequency wet withstand test.
      5) Impulse withstand test.
   b. The Contractor shall provide data to show that the insulator material is resistant to ultra-violet radiation and electrical tracking.
   c. The contact wire unit shall be tension-proof tested to applicable contact wire maximum tension plus design factors of safety.

4. Insulators: Perform following tests in accordance with ANSI C29.1:
   a. Visual and Dimensional Tests:
      1) Entire surface shall be smooth and free from defects.
      2) If adhesives are used, inspect insulator to see that fillet of adhesive provides a complete seal between coating and end fitting.
      3) Verify that both end fittings are in line after being assembled on rod.
      4) Verify that insulator matches approved shop drawings and Specifications.
   b. Flashover Test: Perform on a sampling of not less than 2 percent of each type of insulator in accordance with ANSI C29.1.
c. Mechanical Strength Test: Test insulators at room temperature for 10 seconds to 120 percent of designed tensile, compressive and bending load. Failure shall constitute rejection.

5. Overhead Contact System Conductors:
   a. Perform quality control tests on each reel of wire prior to shipment to site in accordance with applicable standards.
      1) Submit a certified copy of test report for each reel.
      2) Pack a copy of test report with each reel.
   b. Additional Contact Wire Tests:
      1) Test in accordance with ASTM B47.
      2) Twist Test: Test in accordance with ASTM A938 for round wire, except that six twists shall be required. Reject contact wire not meeting twist test.

6. OCS pole mounted, manual, no load break dc disconnect and dc bypass switches:
   a. A mechanical operation test shall consist of the following:
      1) Fully Open disconnect.
      2) Fully Closed disconnect.
      3) Verify there are no signs of binding, galling, uneven wear or other physical tolerance issues.
      4) Verify blade alignment evenly mates on either side of jaw terminal.
      5) All mechanical linkages for manual operating handle assemblies shall move freely and not hinder operation of disconnect.
      6) Disconnect shall be cycled no less than 10 times.
   b. A Dielectric Withstand Test shall be conducted to verify the rated voltage of the switch. Tests shall consist of applying high potential to test points listed below for a duration no less than 1 minute. Voltage applied voltage level shall be no less than twice rated DC voltage plus 1000V. Satisfactory testing will indicate no leakage breakdown current for the duration of the test. Dielectric Withstand Testing shall consist of the following test for each switch:
      1) With switch “closed”, across switch and operator shaft.
      2) With switch “closed”, across switch and base mounting bolts or other metal exposed to exterior of enclosure.
      3) With switch “open”, across ‘jaw’ and ‘hinge’ sides. If multiple switch modules operate as a single device (example: two pole), test each module separately.
   c. Electric Resistance of Current Path
1) The function of this test is to demonstrate that there is a minimum resistance to current flow across the conducting parts of the disconnect switch.

2) With the switch "closed", apply test probes to the ends of ‘jaw’ and ‘hinge” contacts. The resistance shall meet or exceed design test reading for the same or similar type of switch.

7. Poles:
   a. Testing shall be in accordance with Section 34 23 13, Overhead Contact System Metal Poles.

PART 3 - EXECUTION

3.01 MECHANICAL TESTS

A. Upon completion of each OCS line section installation, verify physical integrity of the complete system.

B. Visual Inspection: From ground level, verify the following.
   1. OCS components are correctly installed.
   2. Contact wire poles are vertical.
   3. Tunnel supports and cantilevers are correctly positioned and have correct along track offset.
   4. Steady arms are correctly positioned.
   5. Hangers are plumb and within design position.
   6. Feeder disconnect switch operating mechanisms operate freely and correctly and switch-blade position corresponds to handle position.

C. Hands on inspection: From contact wire level check for the following and remedy any unsatisfactory conditions detected:
   1. Fit and tightness of components.
   2. Split pins and locknuts are secure and in proper location.
   3. Contact wire is free of kinks, twists, nicks or damage.
   4. Stranded wires are free of damage to strands.
   5. Steady arm heel settings and fittings are correct.
   6. Jumpers are of the correct type, have adequate travel capability, are properly fitted and are well formed to avoid fatigue failure.
   7. Hinge fittings have freedom to move under load.
   8. Clearance and insulation between adjacent or crossing contact wires meet specification requirements.
   9. No interference with passage of pantographs, including spots where pantographs could tangle with wires or suspension assemblies.
D. From the Ground: Contractor shall make the following checks:

1. Check that disconnect switch operating handles function correctly and name plates are correctly positioned.

2. Check that the disconnect switches operate easily and that the blades open and close smoothly without sticking.

E. Clearance Tests:

1. Electrical and Mechanical Clearance:
   a. Use a rail mounted height and stagger gauge having the appropriate pantograph clearance envelope.
   b. Electrical:
      1) Measure the electrical clearance from the vehicle pantograph and energized parts of the OCS to non-energized or grounded components or structures.
   c. Mechanical:
      1) Measure the mechanical clearances from the pantograph to OCS support components such as the heels of steady arms and drop brackets.
      2) Measure the mechanical clearances from the pantograph and OCS to fixed structures.
      3) Make corrections for temperature, for fixed termination catenary and for uplift of the conductors.
      4) Clearances shall be equal to or exceed minimum values as specified.
      5) Adjust portions found to have insufficient clearance to provide the required clearance.

2. Vehicle Mechanical Clearances to OCS Supports (excluding Pantograph).
   a. Perform vehicle clearance test using a rail mounted clearance gauge.
   b. Base clearances on the LRV clearance diagram and clearance tables in the Sound Transit Design Criteria Manual appropriate to the section of track being checked and allowing for track curvature, superelevation and track tolerances.
   c. Resident Engineer will provide specific clearance measurements appropriate to section of track being measured. Equipment shall be clear of the clearance gauge by a minimum of 3 inches.
   d. The clearance from face of any OCS structure to track centerline shall be measured at each structure and compared to the vehicle dynamic envelope dimension for the track curvature and superelevation, at that location.
   e. Each part of the OCS structure including pole, switch operating mechanism, cables and cable cleats, etc., which is lower than the LRV
roof line shall be clear of vehicle envelope by a minimum of 6 inches to allow for pole rake, track tolerances and mechanical running clearance.

3. OCS pole mounted, manual, no load break dc disconnect and dc bypass switches:
   a. A mechanical operation test shall consist of the following:
      1) Fully Open disconnect.
      2) Fully Closed disconnect.
      3) Verify there are no signs of binding, galling, uneven wear or other physical tolerance issues.
      4) Verify blade alignment evenly makes on either side of jaw terminal.
      5) All mechanical linkages for manual operating handle assemblies shall move freely and not hinder operation of disconnect
      6) Each disconnect shall be cycled no less than 10 times.

3.02 ACCEPTANCE MEASUREMENTS

A. Prior to conducting field installation tests, verify that OCS equipment is installed according to these Specifications and is in operable condition, and verify physical integrity and quality of workmanship of system installation.

B. Perform only on a completed line section after acceptance of Mechanical Tests A, B, C, D, and E by Resident Engineer.

C. Measure the following in the presence of the Resident Engineer using equipment suitable for obtaining correct measurements:
   1. Contact Wire Height: Distance from contact wire to a line defined by top of both rails at point of measurement (inclined reference point).
   2. Messenger wire height.
   3. Stagger:
      a. Distance from contact wire to super-elevated centerline of track measured at support location.
      b. Measure stagger to nearest 1/2 inch.
      c. Record as L (left) or R (right) when viewed in direction of increasing stationing.
   4. Cross Level (Superelevation):
      a. Difference between elevations of two rails measured at the structure location.
      b. Measure using level and tape measure.
   5. Midspan Offset: Same as stagger except taken at midspan.
   6. Midspan Contact Wire Height: Height of contact wire at midspan.
7. Midspan Cross Level: Measure at midspan.

8. In-Running Contact Wire Height: Height of in-running contact wire at overlaps and turnouts.

9. Out-of-Running Contact Wire Height: Height of out-of-running contact wire at overlaps and turnouts.

D. Compute the following Using Measurements Taken:

1. Sag:
   a. Compute halfway between structures.
   b. Average of contact wire height for previous and next point of attachment minus midspan contact wire height.

2. Gradient (Rate of Change of Contact Wire Height):
   a. Compute between structures.
   b. Compute as difference between contact wire height at 2 adjacent supports divided by distance between supports.

E. Submit and obtain approval for an OCS Acceptance Measurements test data form before tests are scheduled, containing the following information at a minimum:

1. Date: Provide space to enter date measurements were taken.

2. Wire Run Number: Designation shown on Contract drawings.

3. Track: Designation shown on Contract drawings.

4. Equipment Style: The style of catenary being measured.


6. Names: Contractor’s representatives and Sound Transit representative.

7. Page Number: "Page X of XX" where XX is the total number of pages for a wire run.

8. OCS Type: Type of OCS being measured.

9. Measuring Equipment: Description of equipment used.

10. Conductor Temperature: At time of wire measurements in degrees F.
    a. This measurement shall be monitored by the use of a dial-type thermometer inserted into a hole bored lengthwise into a 10 foot length of contact wire.
    b. The thermometer contact wire assembly shall be held under the same ambient conditions as those experienced by the installed OCS.

11. Air Temperature: At time of wire measurements in area of measurements in degrees F.

12. Support structure number.

14. Structure Set Out (Pole Face to Rail Distance): Measured distance from the pole to abutment face to track centerline, taken with tape measure.

15. Foundation Height: Measured height from top of foundation to top of near rail, positive for above rail, negative for below rail.

16. Cross Level (Superelevation):
   a. Difference between elevations of the 2 rails measured at the structure location.
   b. Record as L (left) or R (right) for the direction the track is tilting, or side of track with the low rail, when viewed in the direction of increasing stationing.

17. Stagger:
   a. Distance from the contact wire to the super-elevated centerline of the track measured at the support location. This measurement shall be taken using a catenary position measurement device.
   b. Stagger shall be recorded as L (left) or R (right) when viewed in the direction of increasing stationing. Record stagger to nearest 1/2 inch.

18. Contact Wire Height: Distance from the contact wire to a line defined by the top of both rails at the point of measurement (the inclined reference point).

19. Midspan Offset:
   a. Same as “Stagger” above, except taken at midspan.
   b. Same sign convention applies.

20. Midspan CW Height: Same as “CW Height” above, except measured at midspan.

21. Midspan Cross Level:
   a. Same as “Cross Level” above, except measured at midspan.
   b. Measurement shall be taken using level and tape measure.

22. Sag: The computed average of “CW Height” for the previous and next structure minus midspan contact wire height between the structures.

23. Gradient:
   a. Rate of change of contact wire height.
   b. Computed as the difference between contact wire height at 2 adjacent supports divided by the distance between the supports.

24. Span Length: Along track distance between two OCS supports calculated from as built insert or foundation stationing.

25. In-Running Contact Wire Height: Height of in-running contact wire at overlaps and turnouts.

26. Out-of-Running Contact Wire Height: Height of out-of-running contact wire at overlaps and turnouts.
27. Spaces to enter required measurements and computed values.
28. Remarks, as necessary.

F. Design Compliance:

1. Resident Engineer will use acceptance measurements to determine compliance with design and will inform Contractor of necessary corrections to be performed.
2. Contractor shall execute corrections.
3. After execution of corrections, re-measure and record affected data and submit results to the Resident Engineer.
4. Acceptance measurements will not be considered complete until corrections are made and approved by the Resident Engineer.

3.03 ELECTRICAL TESTS

A. General:

1. Test procedures for Continuity, and Hi-Pot tests shall include diagrams showing which OCS sections will be tested, where grounds will be placed, where jumpers will be placed, and test equipment locations.

B. Continuity Test:

1. General:
   a. The continuity tests serve the following purposes:
      1) Verify that the electrical circuits are continuous from the TPSS out to the OCS and back through the rail to the TPSS.
      2) Confirm that the feeder cables are landed correctly in the TPSS and on the correct OCS section prior to Dielectric testing.
   b. Following mechanical test and acceptance measurements and with the OCS section de-energized, make a series of continuity tests to prove the continuity of each section of OCS and track in the area.
   c. Each OCS test section shall be formed by shorting the OCS to the track with jumpers at one end of the test section (see Figure 3.1). In double track sections, test the individual OCS-track sections separately.
   d. Provide a 12 V battery, current measuring shunt, voltmeter, ammeter, and switch and measure voltage and current.
   e. Take three measurements for each test section and record the results. Average the results of the three measurements.
   f. A passing test shall constitute a nominal loop resistance not exceeding 0.1 ohm per mile of single track OCS construction. Investigate and correct the cause of higher loop resistance values.
C. Dielectric Test:

1. Following continuity test and with the OCS section de-energized and with any surge arrestors disconnected, the Contractor shall connect a 1000 V megger between the OCS and the rail at one end of each test section as shown in Figure 3.2.

2. The resistance in each test shall be recorded on a table.

3. A resistance value of greater than five M ohms is required to be obtained before continuing with the tests described in the Hi-Pot Insulation Testing Section.

4. The Contractor shall replace the 1000 V megger with a dc hi-pot test set and test for leakage current as described in the Hi-Pot Insulation Testing Section.

D. Hi-Pot Insulation Testing:

1. General:
   a. Hi-pot testing through closed disconnect switches is prohibited.
   b. Lightning arresters shall be disconnected during the hi-pot test.
   c. Perform a dc hi-pot test on discrete sections of OCS 1 to 2 miles in length. The hi-pot tests serve the following purposes:

   1) Checks components such as insulators and feeders for leakage.

   2) Verifies the electrical withstand of section insulators and disconnect switches.

   3) Provides a baseline for periodic checks of insulation level of OCS sections, by comparing voltage and leakage current with previously measured values.

   4) A nominal dc hi-pot voltage of 4.5 kV shall be used for the test. Hi-pot tests shall be carried out on the OCS sections as soon as possible after the continuity tests have been completed, in order to ensure that all of the section being tested is electrically continuous and is subjected to the test voltage. Leakage currents
between zero and 5 mA may be expected for section lengths of one to two miles.

2. Safety Precautions:
   a. The hi-pot test requires application of high voltage to the OCS. Proper regard shall be paid to safety.
   b. Clearly identify test zones.
   c. Personnel not directly associated with the tests shall be kept clear of the tracks.
   d. Ground OCS sections adjacent to the section under test.
   e. Hi-pot testing through closed disconnect switches is prohibited.
   f. Lightning arresters shall be disconnected during the hi-pot test.

3. Pretest Verification:
   a. With the OCS section de-energized, connect a 1000 V megger between the OCS and the rail at one end of test section (see Figure 3.2).
   b. Verify that resistance value is greater than 5 M ohms before continuing with the tests.
   c. Record resistance value on the test data sheet.

4. Test Parameters:
   a. Test Equipment: DC hi-pot unit.
   b. Test Voltage: 4500 V.
   c. Maximum Leakage Current: 5 mA per mile at 4500 V.

5. Test Procedure:
   a. Apply DC voltage to the OCS section in 500 V steps up to 4500 V.
   b. At each 500 V step, allow 1 minute to pass to stabilize the level of leakage current.
   c. Hold the test voltage of 4500 V for 60 seconds.
   d. Record the leakage current at each value on a test data sheet.
   e. Record weather conditions and temperature.
   f. Investigate the cause of leakage currents in excess of 5 mA per mile, or unstable current readings.
E. Ground Resistance Measurements for Surge Arrestors:

1. General: Each contractor shall be responsible for testing grounding facilities that they installed. Prior to acceptance, the ground resistance of the ground connections for the surge arrestors shall be measured and recorded in accordance with the test procedure. Grounds for surge arrestors with a ground resistance measurement greater than 5 ohms shall be supplemented by adding ground rods until a grounding resistance of 5 ohms or less is achieved.

2. Procedure:
   a. Connect the megger as shown in Figure 3.3. Note that the lead from P1C1 should be as short as possible and that the electrodes and the ground rod shall be in a straight line. It is not essential for the electrodes to be parallel to the track, but this configuration may be the most convenient.
   b. Position the electrodes at distances as shown in Figure 3.3 test position 1, i.e. with x = 66 feet y = 105 feet. To ensure acceptance values of resistance, the ratio of distance (x/y) shall be approximately 62 percent. Insert current and potential electrodes into the earth to about 6 to 10 inches. For very dry soil pour water around the current electrode. Measure and record the resistance.
c. Keeping the x dimension the same as in step b, reposition the current electrode to y + 6 feet. Measure and record the resistance.

d. Compare the resistance values obtained in steps 2 and 3. If the readings obtained are within 5 percent of each other, no further measurements are required and the average value should be used as the actual resistance. If the readings differ by more than five percent, increase x by 10 feet and make y equal to \((x + 10) / 0.62\) approximately. Repeat steps two, three and four as necessary.

e. Repeat this procedure for each surge arrester location for which a ground resistance measurement is required.

f. A measured ground resistance value of 5 ohm or less is considered acceptable.

### 3.04 OCS ENERGIZATION TEST

A. In conjunction with the traction power substation testing energize each electrical section of the OCS under the direction of Resident Engineer.

B. Test each section to determine proper functioning of each disconnection device including switches and circuit breakers.

C. Test each section to verify separation of sections by section insulators or overlaps.

### 3.05 SYSTEM INTEGRATED TESTS

A. Upon completion of the Acceptance Measurements, Mechanical Tests, Clearance Tests, and Electrical Tests, initiate a low speed de-energized LRV test run to confirm acceptable pantograph performance.
B. Perform a visual inspection of the pantograph interface to the wire in conjunction with the Resident Engineer.

1. Demonstrate that pantograph passing electrical clearances are adequate, that there is no physical interference with pantograph movement, and that pantograph security is sufficient.

2. During this test, Contractor shall have available plant, equipment, and labor able to perform minor modifications to the OCS equipment.

3. Contractor shall supply pantograph clearance cart with the appropriate pantograph clearance envelope for testing.

C. Video Test:

1. Camera Mount: 1/2 inch thick phenolic board, approximately 1 foot by 2 feet, perforated with a sufficient number of holes to reduce surface area by half, to fit Sound Transit pantograph. Mount video camera to phenolic board on LRV pantograph.

2. CCTV Camera: Lightweight, metal body, digital, color, 120 V power, wide angle lens.


4. Cabling: Video and power cable sufficient to connect pantograph mounted camera to video recorder inside LRV.

5. Perform tests to verify the following:
   a. No visible contact losses between the vehicle pantograph head and the contact wire.
   b. Acceptable wire tracking up to the maximum permissible speeds under normal operating conditions.
   c. Pantograph passing electrical clearances are adequate.
   d. No physical interference with pantograph movement.
   e. Specified pantograph security.
   f. No arcing as pantograph transverses OCS.

END OF SECTION
SECTION 34 23 79
OVERHEAD CONTACT SYSTEM CAPITAL SPARE PARTS AND MAINTENANCE EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
   1. Quantity and type of spare parts for Overhead Contact System.

1.02 SUBMITTALS
A. Maintenance Material Submittals:
   1. Submit:
      a. List of required spare parts.
      b. List of required special tools and test equipment.
      c. List of additional recommended spare parts.

PART 2 - PRODUCTS

2.01 REPLACEMENT PARTS
A. Capital Spare Parts: Include required spare parts and parts ordered by Sound Transit.
   1. Supply a spare parts list with Sound Transit part designation and manufacturers part number.
   2. Provide a fixed unit price that is valid for one year after delivery for each part on the required spare parts to be furnished under the Contract.
   3. Beyond one year, part costs are to be escalated in accordance with mutually agreed upon indices.

B. Spare Parts for Warranty Repairs:
   1. The required spare parts or the spare parts ordered by Sound Transit for support of operations are not to be used by the Contractor for warranty repairs and/or warranty parts replacements.
   2. Sound Transit will not be responsible for receiving or storing any parts for warranty support.
   3. At the end of the warranty period, Sound Transit may consider a negotiated price for purchase of parts stocked by the Contractor for warranty support.

C. Availability of Replacement Parts:
   1. Guarantee parts availability for a period of 10 years from Contract award date.
2. Provide the detailed manufacturing drawings to Sound Transit at the end of the 10-year period or when the availability of parts ceases if within 10 years of the Contract award date.

D. Special Tools and Test Equipment:
   1. Provide special tools and test equipment.
   2. Special tools include but are not limited to fixtures, equipment, gages, hand tools, power tools, motors, or other tools and equipment necessary to troubleshoot, maintain, repair, overhaul, assemble and disassemble the overhead contact system (OCS) that are not commonly available from commercial tool suppliers.

2.02 REQUIRED SPARE PARTS

A. Provide Required Spare Parts as listed. This list shall be reviewed by ST prior to purchase to allow type and quantity changes for equivalent value of materials.
   1. Provide 1 of each OCS pole type and size included on the project.
   2. Provide 2 of each assembly, sub assembly or component supplied on the Project.
   3. Conductors:
      a. 5000 linear feet contact wire.
      b. 5000 linear feet messenger wire.
      c. 200 linear feet jumper cable.

2.03 RECOMMENDED SPARE PARTS

A. Furnish a list including description, part number, quantity and unit price of contractor or manufacturer recommended spare parts. Sound Transit may or may not exercise purchase of the recommended Spare Parts.
   1. Provide a fixed unit price that is valid for one year after delivery for each part on the required and recommended spare parts list above and beyond the required spare parts list to be furnished under the Contract.
   2. Beyond one year, part costs are to be escalated in accordance with mutually agreed upon indices.

PART 3 - EXECUTION

3.01 DELIVERY OF SPARE PARTS

A. Provide Resident Engineer notice of delivery.

B. Do not ship spare parts until authorized by Resident Engineer.

C. Spare parts shall be delivered to a Sound Transit designated location in the greater Seattle, Washington metropolitan area.
SECTION 34 25 00

TES CAPITAL SPARE PARTS AND MAINTENANCE EQUIPMENT GENERAL

PART 1 - SUMMARY

1.01 SECTION INCLUDES:

A. Quantity and type of spare parts shall be provided by Contractor.

B. Requirements for spare parts and maintenance equipment.

1.02 SUBMITTALS

A. Submit all items described below:

1. List of mandatory spare parts.

2. List of mandatory special tools, test and maintenance equipment for each TPSS.

3. List of additional recommended spare parts, special tools, and test and maintenance equipment. Recommended special tools, test and maintenance equipment that can be shared by substations shall be listed separately.

4. Provide part numbers for each part, including a detailed breakdown of each spare part assembly and set.

1.03 DELIVERY, STORAGE AND HANDLING

A. Delivery of Spare Parts:

1. Furnish Resident Engineer notice of delivery, a minimum of three Days before delivery.

2. Do not ship spare parts until authorized by Resident Engineer.

3. Spare parts to be delivered to a location designated by Sound Transit.

4. Package and label spare parts in moisture-proof containers suitable for shipment and storage. Attach copies of shipping list in the package and to the exterior of the package.

5. Unload the spare parts in a manner that will prevent damage to the packages and the contents. Sound Transit will open the packages and inspect spare parts for damage. Damaged parts will be returned to Contractor to be replaced with undamaged parts and materials, at no additional expense to Sound Transit.

6. Cable shall be delivered on reels constructed of metal or of equivalent durable material (wood reels are not acceptable).
PART 2 - PRODUCTS

2.01 REPLACEMENT PARTS

A. Mandatory Capital Spare Parts:
   1. Provide a fixed unit price that is valid for one year after delivery for each part on the required and recommended spare parts list and beyond the required spare parts list to be furnished under the Contract.
   2. Beyond one year, part costs are to be escalated in accordance with mutually agreed upon indices.

B. Spare Parts for Warranty Repairs:
   1. The capital spare parts or the spare parts ordered by Sound Transit for support of operations are not to be used by the Contractor for warranty repairs and warranty parts replacements. Sound Transit will not be responsible for receiving or storing any parts for warranty support.
   2. At the end of the warranty period, Sound Transit may consider a negotiated price for purchase of parts stocked by the Contractor for warranty support.

C. Availability of Replacement Parts:
   1. Guarantee parts availability for a period of 10 years from Contract Award.
   2. Furnish the detail manufacturing drawings to Sound Transit at the end of the 10 year period or when the availability of parts ceases after that date.

2.02 MANDATORY SPECIAL TOOLS, TEST AND MAINTENANCE EQUIPMENT

A. Special tools include but are not limited to fixtures, equipment, gages, hand tools, power tools, motors, or other tools and equipment necessary to troubleshoot, maintain, repair, overhaul, assemble and disassemble the TPSS that are not commonly available from commercial tool suppliers.

B. Provide one set of mandatory special tools, test and maintenance equipment for each TPSS and section tie breakers to perform corrective and preventative maintenance operations. Tools shall consist of those required to disassemble, adjust, and reassemble components. For all maintenance functions, standard tools, wrenches, etc. commercially available are not required.

C. Specified Special Tools:
   1. Refer to Section 34 21 16.21, TPSS – Control Power, for battery maintenance tools.
   2. Refer to Section 34 21 16.23, TE Substation Local Centralized Monitoring System and Intelligent Electronic Devices, for laptops and associated software for maintenance to be purchased at beginning of the Project.
   3. Refer to 34 21 16.26, Transformer Rectifier Unit, for tools to remove or install diodes, fuses, and hardware.

2.03 MANDATORY SPARE PARTS

A. Table in Part 3 lists mandatory spare parts.
B. Definition of “set” in table below: The quantity of the stated part that is provided as part of one substation. For example, if the part is “LEDs for Dc Switchgear,” and 1 substation has 2 red LEDs, 2 green LEDs, and 1 white LED for Dc Switchgear, regardless the types and quantity of Dc Switchgear, then 4 sets consists of 8 red LEDs, 8 green LEDs, and 4 white LEDs.

C. Definition of “assembly”: A unit consisting of components or parts that have been fitted together to form a self-contained device or fixture.

D. The mandatory spare parts list shall be reviewed by ST prior to purchase to allow quantity changes or substitute for recommended spare parts within equivalent value of materials.

2.04 RECOMMENDED SPARE PARTS

A. Furnish list, description; break down part number and list, recommended quantity and unit price of spare parts, special tools, test and maintenance equipment recommended in submittal. Sound Transit may or may not exercise purchase of any or all of the recommended items.

PART 3 - EXECUTION

3.01 SCHEDULES

A. Mandatory Spare Parts

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Rectifier Diodes</td>
<td>15</td>
</tr>
<tr>
<td>2</td>
<td>15 kV/26kV Drawout Circuit Breaker member compete with all hardware and devices including truck, if TPSS breaker is a different manufacturer than ac substation breakers</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>12.5 kV/26kV Revenue Class PT and CT’s</td>
<td>3 sets each</td>
</tr>
<tr>
<td>4</td>
<td>Rectifier Diode Protection Fuses</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>ANSI CIRCUIT 31 Interphase Transformer</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Dc 6000 Amp Main Positive Circuit Breaker Element with Truck and Accessories</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Main Contacts for 6000 Amp Dc Circuit Breaker</td>
<td>1 assembly</td>
</tr>
<tr>
<td>8</td>
<td>Secondary Contacts for 6000 Amp Dc Circuit Breaker</td>
<td>1 assembly</td>
</tr>
<tr>
<td>9</td>
<td>6000 Amp Negative Disconnect Switch</td>
<td>1 assembly</td>
</tr>
<tr>
<td>10</td>
<td>Diode Temperature Monitors</td>
<td>7 assemblies</td>
</tr>
<tr>
<td>11</td>
<td>33 Switches (Micro Switches)</td>
<td>20 assemblies</td>
</tr>
<tr>
<td>12</td>
<td>12.5 kV/26 kV Traction Power Transformer and temperature monitor*</td>
<td>1 assembly*</td>
</tr>
<tr>
<td>13</td>
<td>Auxiliary Transformer 12.5 kV/26kV</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>Dc 4000 Amp Feeder Circuit Breaker Element Complete with Truck and Accessories</td>
<td>5</td>
</tr>
<tr>
<td>Item</td>
<td>Description</td>
<td>Quantity</td>
</tr>
<tr>
<td>------</td>
<td>-------------------------------------------------------------------</td>
<td>---------------------------</td>
</tr>
<tr>
<td>15</td>
<td>Main Contacts for 4000 Amp Dc Circuit Breaker</td>
<td>15 assemblies</td>
</tr>
<tr>
<td>16</td>
<td>Secondary Contacts for 4000 Amp Dc Circuit Breaker</td>
<td>15 assemblies</td>
</tr>
<tr>
<td>17</td>
<td>1500 Vdc Protective Relays – of each type</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>1500 Vdc Switchgear Control and Auxiliary Relays – of each type</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>Rail Voltage Monitoring and Grounding System</td>
<td>1 set</td>
</tr>
<tr>
<td>20</td>
<td>1500V Dc Circuit Breaker Charging Motors</td>
<td>4</td>
</tr>
<tr>
<td>21</td>
<td>1500V Dc Circuit Breaker Solenoids – set</td>
<td>4</td>
</tr>
<tr>
<td>22</td>
<td>1500V Dc Circuit Breaker Springs – set</td>
<td>4</td>
</tr>
<tr>
<td>23</td>
<td>LEDs for Dc Switchgear</td>
<td>4 sets</td>
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<tr>
<td>24</td>
<td>Ac and Dc LV Circuits’ Fuses for Dc Switchgear</td>
<td>40</td>
</tr>
<tr>
<td>25</td>
<td>Dc Transducer – 4000 Amp.</td>
<td>4 sets</td>
</tr>
<tr>
<td>26</td>
<td>Dc 4000 Amp Disconnect Switch Assembly</td>
<td>1 each type</td>
</tr>
<tr>
<td>27</td>
<td>Battery Charger</td>
<td>1 set each type</td>
</tr>
<tr>
<td>28</td>
<td>Battery Cells</td>
<td>4</td>
</tr>
<tr>
<td>29</td>
<td>Local Centralized Monitoring System IC and HMI</td>
<td>1 set</td>
</tr>
<tr>
<td>30</td>
<td>Dc Transducer – 6000 AMP</td>
<td>1</td>
</tr>
<tr>
<td>31</td>
<td>Substation wide LV Ac and Dc Contactors (including control system)</td>
<td>2 sets</td>
</tr>
<tr>
<td>32</td>
<td>1500 Vdc Indicating Meters</td>
<td>1 set</td>
</tr>
<tr>
<td>33</td>
<td>Electro-Mechanical Interlocks – each type</td>
<td>1 set</td>
</tr>
<tr>
<td>34</td>
<td>Load Measuring Resistors</td>
<td>30</td>
</tr>
<tr>
<td>35</td>
<td>Load Measuring Contactor</td>
<td>5</td>
</tr>
</tbody>
</table>

* No spare is required if the installed assembly is electrically and physically interchangeable with existing ST system.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. External cable manufacture, testing, and installation.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

   a. Part 10 – Wire and Cable
   b. Part 13 – Mechanical
   c. Part 14 – Electrical Devices, Foundations, and Hardware

   a. ASTM B3 - Specification for Soft or Annealed Copper Wire.
   b. ASTM B8 - Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
   c. ASTM B33 - Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes.

3. Insulated Cable Engineers Association (ICEA)
   b. ICEA T-33-655 Low Smoke, Halogen-Free Polymeric Jackets

4. Institute of Electrical and Electronic Engineers (IEEE)

5. National Electrical Contractors Association (NECA)
   a. Standard Practice of Good Workmanship in Electrical Construction

6. National Fire Protection Association (NFPA)
a. NFPA 70 - National Electrical Code (NEC)

7. Underwriter’s Laboratories (UL)
a. UL 44 - Extruded Insulated Tubing

1.03 SUBMITTALS
A. Submit:
   1. Product Data: Manufacture product datasheets and complete technical data for the cable and ancillary devices proposed to furnish demonstrating compliance with requirements of these Specifications for each proposed cable type.
   2. Cable Manufacturer Documents including qualification data.
   3. Shop Drawings: Cable Installation Plans and Cable Pulling Report: In accordance with requirements of NEC and per manufacturer’s recommendations.
   4. Testing Documents: Provide certified test reports for factory testing of signal cables.
   5. Quality Assurance Program.

1.04 QUALITY ASSURANCE
A. Manufacturer Qualifications:
   1. Manufacturer shall supply evidence of a minimum of 15 years reliable experience in supplying vital circuit signal cables of type specified on at least five Class I railroads or transit properties with a minimum of 2,000,000 cable feet installed.
   2. A letter from each proposed wire and cable manufacturer, on manufacturer’s letterhead, certifying that proposed manufacturer has a copy of the Contract Section 34 42 08, External Signal Cable and proposed manufacturer will fully comply with requirements of these Specifications.
   3. Quality Assurance Program: Demonstrate compliance with Quality Assurance Program that ensures a thoroughly tested cable with long service life. Focus will be on formal assurance that cable failure cannot be attributed to actions or lack of actions by the manufacturer.

B. Wires and cables shall meet or surpass tests and requirements specified in AREMA, Part 10.3.

1.05 DELIVERY, STORAGE AND HANDLING
A. Delivery and Acceptance Requirements:
   1. Shipping:
      a. Provide cable closely and tightly wound in a uniform manner, in each layer, on reels. Wind each length of cable on a separate reel.
b. Manufacturer shall be responsible for change in shape of cable occurring in normal transit which results in an increase in maximum diameter beyond that specified.

c. External protective wrapping on reels shall be secured by at least two steel bands to ensure damage free shipment.

B. Reels:
1. Diameter: Minimum 12 times cable diameter.
2. Arbor Hole: Admit a spindle 2-1/2 inches in diameter without binding.

C. Cable Ends:
1. If inner end of cable projects through flange of reel, protect inner end with suitable cover of metal, having rounded ends and sides, and securely fastened in place to protect cable end.
2. Secure both ends of cable on reel to prevent their becoming loose in transit or handling of reel. Secure inner end of cable but ensure it is accessible and protected from injury.
3. Protect both ends of each length of cable with wrappings of rubber and plastic tape, or an effective boot taped or sealed into place. Seal cable against entrance of moisture after passing factory tests.
4. Do not use friction tape, other than an external mechanical protection over an adequate rubber and/or plastic tape.
5. Provide cable end protection adequate to protect cable in shipment and prolonged external storage in the weather.
   a. Markings: Paint an arrow on one head of each reel, greater than 38 inches, pointing opposite direction from outer end of cable with words "Roll This Way". Provide letters not less than 3/4-inch height and an arrow not less than 6 inches in length and 1/2 inch in width.

D. Handling Requirements: In accordance with AREMA Part 10.4.1.

E. Storage: Store wire and cable in secure and dry storage facility, in accordance with National Electrical Contractors Association (NECA) 1.

PART 2 - PRODUCTS

2.01 CABLE

A. General:
1. Environment: Minus 40 to 90 degrees C.
2. Rated life: 40 years minimum.

B. Individual Conductors:
1. Material: Soft annealed copper conforming to ASTM B3.
2. Coating: Continuous tin, lead, or lead alloy conforming to ASTM B33 or B189.
5. Conductors: Free of longitudinal or lateral nicks and scratches, uniform in gauge.

C. Insulation:
1. Material: Vulcanized ethylene-propylene rubber (EPR) compound, in accordance with AREMA Part 10.3.19, homogeneous in character, tough, elastic, tight fitting, and applied concentrically about conductor.
2. For Tunnel applications the cable shall meet requirements of NFPA130 (Fixed Guideway Transit and Passenger Rail Systems) part 12.2 for flame spread and smoke release. The manufacturer shall select insulation materials as necessary to meet these requirements. Voltage Rating: 600 V.
3. Insulating Compound: Clean and free stripping, leaving coated conductor, upon stripping, unimpaired, and ready for soldering.
4. Thickness: Minimum thickness in accordance with Table 10316-1, AREMA Part 10.3.16.
5. Identification: Numbers (both number and work number, i.e. "1 - one") in accordance with ICEA, Method 4; duplicated on opposite sides of each conductor at intervals of not more than 6 inches.
6. Manufacturer shall formulate and compound conductor insulating materials in their own plant. Conductor insulating materials and cable outer coverings shall also be applied, assembled, and tested in their own plant(s).

D. Wire and Cable Jacket:
1. Physical Characteristics: black, low-density, extruded over insulation, in accordance with ICEA S-95-658.
2. Non-tunnel applications, only: high-molecular weight polyethylene (PE) compound, in accordance with AREMA Part 10.3.21.
3. Tunnel applications: cross-linked polyolefin (XLPO), low smoke zero halogen (LSZH), in accordance with AREMA Part 10.3.13. This cable type may also be used for non-tunnel applications.
4. Thickness: Minimum thickness in accordance with Table 10316-4 in AREMA Part 10.3.16.

E. Multi-Conductor Cables:
1. Assembly: Comply with requirements of ICEA S-95-658 and AREMA Part 10.3.16, Recommended Design Criteria for Signal Cable, Non-Armored.
2. Fillers: comply with AREMA Part 10.3.16, Recommended Design Criteria for Signal Cable, Non-Armored.
3. Track Circuit Cable: Twisted Pair Lay Ratio: 12 times circumscribed diameter of cable pair.
2.02 IDENTIFICATION

A. Single Conductor Cable: Print manufacturer, year of manufacture, voltage rating, and wire size on surface of jacket; maximum interval 24 inches.

B. Multi-Conductor Cable: Moisture resistant marker tape under jacket and on the surface of outer jacket parallel to longitudinal axis of cable; print manufacturer, year of manufacture, voltage rating, number of conductors, and wire size; maximum interval 30 inches.

C. Wire Tags:
   1. Approved Manufacturers: Brady HEATEX™ labels or approved equal.
   4. Print: Cable origin, function, and destination.

D. Cable Tags
   1. Non-fading, plastic, printed cable tags with holes for attachment to cable with nylon cable ties.
   2. Product: Almetek Industries E-Z Tags with plastic slide in holder or approved equal. Size 2 inch by ¾
   3. Print: Cable destination and number of conductors in cable as described in Contract Drawings.

2.03 INSTALLATION MATERIALS AND EQUIPMENT

A. Cable Pulling Lubricant: Selection of cable pulling lubricant shall be based on type of cable and ambient conditions. Product shall be non-petroleum based that will not damage cable sheathing or insulation or cause corrosion to metal boxes or hardware of the raceway or signal system.
   1. Product shall be approved by the cable manufacturer.
   2. Product shall meet the requirements of IEEE 1210.
   3. For non-low smoke cable provide lubricant selected based on the ambient temperature. For normal ambient temperature lubricate with Polywater J; or WJ; or approved equal.
   4. Where a lower temperature causes a need for a lower coefficient of friction utilize Aqua-Gel or Aqua-Gel CW; or approved equal.

B. Where low smoke cable is used, such as in a tunnel, use a Low Smoke Cable Pulling Lubricant product specifically formulated to work with that material such as Polywater LZ; or approved equal.

C. Concrete Tie, Rail Cable, and Wire Clips: Stainless steel.

D. Terminals: Stranded wire, compression-type, insulated wire terminals, in accordance with AREMA Part 14.1.1 and the following solderless insulated crimp terminals:
   1. Terminals shall have insulation support designed in such as the Tyco AMP PIDG series with catalogue numbers identified for a one-quarter in stud. For
terminating on another size stud the Contractor shall select an alternative part number of the same type.

2. For terminating insulated wires Awg 12 – 10 – AMP part number 35273.
3. For terminating insulated wires Awg 14- 16 – AMP part number 320563
4. For terminating insulated wires Awg 22 – 16 – AMP part number 320571

E. Crimp Tools.
1. Type: Ratchet, does not release unless wire terminal has been compressed to proper thickness.
2. Calibration: At manufacturer’s specified intervals, use gauges provided by crimp tool manufacturer.

2.04 SOURCE QUALITY CONTROL
A. Factory Design Tests:
1. Wire and cable manufacturers shall meet the following qualification requirements for synthetic rubber insulation, in order to be approved for use on these signal circuits. Insulation failure shall not occur during these tests. Supply full documentation on tests and test results.
   a. Voltage Aging Test (Dry): Test sample in free air with a minimum of 10 feet between terminals, continuously energize insulated conductor, without coverings over insulation, in accordance with one of the following stresses to voltage age the sample shown below in Table A.
   b. Voltage Aging Test (Wet): Immerse test sample in at least 10 feet of water at room temperature, ground shield, continuously energize insulated conductor, without coverings over insulation, in accordance with one of the conditions shown below in Table B.
   c. Step-Voltage Test: Apply test voltages of 60 Hz ac increased in 10 kV steps for 5 minutes at each step to voltage-aged sample until breakdown occurs. Breakdown shall be at a test voltage level greater than 350 volts/mil.
   d. Thermal Aging Test: Test sample in a circulating-air oven using 80-mil-thick slabs. Elongation shall not be less than 50 percent after a minimum aging time of 25 hours at 135 degrees C and 100 hours at 121 degrees C.
   e. Insulation Test: In accordance with ICEA S-95-658.
   f. Jacket Test: In accordance with ICEA T-33-655.

| Table A |
|-----------------|-----------------|
| 60 Hz AC VOLTAGE PER MIL OF INSULATION | TIME - YEARS |
| 225 | 2 |
| 180 | 3 |
| 135 | 5 |
### Table B

<table>
<thead>
<tr>
<th>DC VOLTAGE PER MIL OF INSULATION</th>
<th>TIME - YEARS</th>
</tr>
</thead>
<tbody>
<tr>
<td>325</td>
<td>2</td>
</tr>
<tr>
<td>280</td>
<td>3</td>
</tr>
<tr>
<td>240</td>
<td>4</td>
</tr>
<tr>
<td>200</td>
<td>6</td>
</tr>
</tbody>
</table>

#### B. Factory Production Tests:

1. **Samples:**
   - Production testing in accordance with ICEA S-95-658.

2. **Test Reports:** List test results, date tests were performed, and signature of person who conducted tests.

3. **Insulation:**
   - Physical and Electrical Characteristic Tests: In accordance with AREMA Part 10.3.19.
   - Polyethylene Jacket: In accordance with AREMA Part 10.3.21.
   - Impedance Bond Cable Test: In accordance with AREMA Part 10.3.19 and American Association of Railroads (AAR) Specification 581.3.

4. Perform Dry, Ac Voltage (Wet Tank), and Insulation Resistance Conductor tests on every individual length of insulated conductor, prior to application of outer jacket or braid and prior to cabling or twisting.

5. Perform Ac Voltage, Insulation Resistance Cable, and Dc Resistance final tests on every conductor in every individual length of finished cable, while on shipping reel.

6. Ac Voltage, Dc Voltage, Dc Spark Test: In accordance with NEMA HP 100.


8. Insulation Resistance Cable Test: In accordance with AREMA Part 10.3.19. Perform after ac voltage test.


10. Test every individual length of completed shielded cable for shield continuity.

#### 2.05 SIGNAL SYSTEM CABLE TYPES

**A.** Audio Frequency Track Circuits: Twisted pair No. 14 (minimum) AWG conductors.

**B.** Power Frequency Track Circuit House Connections: Twisted pair No. 6 (minimum) AWG conductors (from signal room to trackside junction box).
C. Power Frequency Track Circuit Rail Connection Cable: No. 6 (minimum) AWG conductors (from signal house to trackside junction box and junction box to rail).

D. Switch-and-Lock Movements.
   1. Power: Three, No. 6 (minimum) AWG conductors, for long cable runs up size the cable to ensure proper operation and performance of the switch machine installed.
   2. Control: Twelve, No. 14 (minimum) AWG conductors.

E. TWC Interrogator Cable: Two, Twisted pairs No. 12 AWG (minimum) shielded.

F. Power Feeders: For signal houses, switch heater cases, and TWC case power furnish cables meeting or exceeding wire size as required by the NEC. Allow a 5 percent maximum voltage drop. Minimum power feeder size shall be Two, No. 6 (minimum) AWG with a ground.

G. LRV Signals:
   1. Three-Aspect: Seven conductor, No. 14 (minimum) AWG.
   2. Two-Aspect: Five conductor, No. 14 (minimum) AWG.
   3. Multi-Aspect Alpha-Numeric: Minimum of two more than the working wires required by the signal, No 14 (minimum) AWG.

H. Rail Temperature Sensor: Five conductor, No. 14 AWG from the control cabinet to the rail temperature sensor junction box.

I. Vital Link from Signal House to Crossing House, Yard Signal House, or remote Signal House/ Case: 12 or 19 conductor, No. 14 AWG if a vital serial link is not practical.

J. Gate 12 volt power to motor: Three conductor No. 6 (minimum) AWG. Power calculations should demonstrate the adequacy of the conductor size.

K. Crossing Flashers: Seven conductor No. 9 (minimum) AWG.

L. Gate Control: Seven conductor No. 14 (minimum) AWG, for both bell driver and indications of gate position.

M. Speed Command Loops:
   1. Single conductor, No. 8 AWG
   2. Class C (19 strand)
   3. 60 mils of heat and moisture resistant, ethylene propylene rubber (EPR) insulation.
   4. 80 mils of heat, moisture, and UV resistant, polyurethane (PUR) jacket.

N. Traction power return and power bonding cables: 250 kcmil 646 stranding and 500 kcmil1225 stranding.

O. Switch heating element power and control cables: size, jacket, and insulation in accordance with specification section on low-voltage conductors and cables.

P. Use single conductor No. 14 wire for interconnecting signal junction boxes with other miscellaneous equipment.
Q. Spare Audio Frequency Track Circuit Cables: Provide and test a spare audio frequency track circuit cable (two conductors) to north and south of each signal room for each track. Install each spare track cable to far-end, of farthest track circuit controlled from signal room for each track. Terminate cable in junction box at that location.

PART 3 - EXECUTION

3.01 PERFORMANCE
A. Provide cable required for Signal System wiring, external to signal rooms and factory wired mechanisms.
B. Size conductors and cable makeup for application of Contractor’s final design. Increases in required conductor size shall be in accordance with National Electrical Code. Size conductors to allow no more than a five percent voltage drop between power source and load, under maximum calculated load conditions. Use larger conductors if required to meet equipment manufacturer’s application requirements.
C. No point-to-point redundancy of wires for increased current capacity is allowed. Cables for equipment in tunnel right of way shall be run in their respective bores.
D. Power Feeder cables to signal houses or cases or any cable carrying higher than 120 volts shall be run in separate conduit from any signal equipment cables.

3.02 INSTALLATION - GENERAL
A. Cable installation shall be in accordance with NEC and manufacturer’s recommendations.

3.03 TERMINATIONS
A. Termination Technique: Use tools and techniques recommended by terminal manufacturer.
B. Terminate cables on AAR terminals with maximum two wires on one AAR terminal binding post. Provide strain relief where needed. Provide sufficient slack in cable conductors at terminating posts to enable three re-terminations of conductors without re-servicing or re-dressing cable. Provide sufficient slack for shock and vibration induced movements, equipment shifting, alignment, cover removal, and component replacement, removal, and inspection.
C. Remove outer sheath of multi-conductor cable such that insulation is not nicked at point of cable entrance. Apply two layers of plastic electrical tape to end of cable sheath or covering to prevent accumulations of moisture or foreign matter.
D. Spares: Terminate spare conductors at entrance rack end and on terminal strips at junction boxes. Properly insulate spare conductors at rails to prevent an unintended connection. Complete connections with double nuts torqued to rated value of nut.
E. Use a single washer on top of terminal for compression-type insulated terminal connections to terminal blocks. Wire terminals require two washers for one terminal, three washers for two terminals.
F. Junction Box Wiring: Terminate external wires and cables at multiple post terminal blocks in accordance with AREMA Part 14.1.6 with wire terminals on one post and link connector type in accordance with AREMA, Figure 14115-1 to complete circuit.
END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:
   1. Power switch mechanism design, factory testing, and installation.
   2. Switch-and-lock movement layout design and installation.
   3. Switch heater design and installation.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.
      a. Part 1, General
      b. Part 12, Switches

1.03 SUBMITTALS

A. Submit:
   1. Product Data:
      a. Description and catalog cut of proposed power switch-machine with sufficient information to identify dimensions and including proven equipment history in North America.
      b. Graphite lubricant proposed for use on switch tie plates.
      c. Description and catalog cuts of switch heater and controls.
   2. Shop Drawings:
      a. Drawings for top line assembly of power switch-and-lock movement layouts together with a bill of materials for both point switches and, if applicable movable point frog switches.
      b. Installation drawing showing gauge plate extensions and mounting details of power switch-and-lock movement layouts, including connections to track switch points. Coordinate with track design to identify spacing of plinths, interface scope between track and signals, method of assuring electrical isolation from rail to machine and ground and isolation from switch machine to any ground.
c. Installation drawings for the switch snow melting equipment. Include heater type, location, and mounting details as part of drawing submittal.

d. Circuit and installation drawing for switch snow melting equipment control cabinets and schematic of the complete subsystem.

3. Testing and Certifications:

   a. General: Submit documents in accordance with Section 01 95 00, System Testing and Integration and Section 34 42 98, Signal System Testing.

   b. Test Procedures for switch machine factory test.

   c. Certified Test Reports for factory testing prior to shipment of switch layouts

   d. Submit a factory test procedure for the switch snow melting cabinet.

PART 2 - PRODUCTS

2.01 PERFORMANCE

   A. Design Requirements:

      1. Size Wiring from signal room to switch machine to prevent voltage at machine motor terminals from dropping below 90 percent of voltage (nominal 110 Vac) inside signal room, when switch is throwing against an obstruction and a properly adjusted clutch is slipping.

      2. Insulate switch layouts to maintain, over life of installation, a minimum of 1,000 ohms resistance between two running rails and also a minimum of 1,000 ohms resistance between running rail and ground and between switch machine and ground.

2.02 MATERIALS

   A. Power Switch-and-Lock Movements:

      1. Model: Ansaldo, Style M-23E or M-3E; Alstom, Model 4000E; or approved equal.

      2. Lock Rods and Detector Rods: Double adjustable type.

      3. Throw rods. Provide basket connector to track work unless the Contract Documents specifically identify the basket as supplied by others.


      6. Motor Voltage Range: 110 - 120 VDC.

   B. Rods and Hardware:

      1. Offsets: To be provided at time of manufacture.

      2. Front Rods: Swivel type, insulated, adjustable.

   C. Junction Boxes (JB): In accordance with Section 26 05 33, Raceways and Boxes.
D. Junction Box Wiring: Insulated flex wire, No. 14 AWG, 19 strand, minimum.
E. Lubrication: Graphite.
F. Paint: Black.

2.03 SWITCH SNOW MELTING EQUIPMENT

A. Contract Drawings shall identify for each interlocking whether that one needs the complete snow melter equipment, including cabinet, heating elements and sensors, or if that interlocking only requires snow melting infrastructure to enable easy future installation of a snow melter subsystem.

B. Switch Heater infrastructure shall consist of:
   1. Control Cabinet foundation.
      a. Provide Control Cabinet foundations in ballasted track unless the Contract Drawings identify the foundation will be furnished and installed by the Civil Contractor.
      b. Provide Control Cabinets foundations in DF track.
   2. Minimum 2 inch Galvanized Rigid Steel (GRS) conduit from the control cabinet foundation to a 12" by 12" by 6" deep stainless steel National Electrical Manufacturers Association (NEMA) 4X Junction Box, with a hinged lid, at each turnout for heating element power distribution.
   3. 1-1/4 inch GRS conduit from the control cabinet foundation to a 10" by 10" by 4' deep stainless steel NEMA 4X Junction Box, with a hinged lid, at each switch machine, for rail temperature sensor and other future control devices.
   4. Additional electrical panel capacity for 9 kVA per turnout at all locations that only switch heater infrastructure are installed. Provide conduit capacity from the designated power source connection point to the control cabinet foundation.

C. Provide Switch Heater Elements and Control Cabinets at the locations as shown on the Contract Drawings. At all other interlocking locations furnish only infrastructure (including power available at a connection point, designated space for the cabinet, and any conduits that must be embedded) so Sound Transit can install Elements, cable connections, and Control Cabinets at future time without rework:

D. Provide rod type heating elements for both the normal and reverse points:
   1. 240 Volt with a single ended electrical connection design.
   2. 150 watts per foot.
   3. Stainless steel construction with a flat side that shall be held against the rail by stainless steel clips to maximize thermal transfer to the rail.
   4. Crib heating elements for the detector, throw, and lock rods.
   5. Point heating elements for both the normal and reverse points.

E. Heater Control Cabinet: Provide for each identified interlocking:
   1. Steel construction with a NEMA 4 rating.
   2. Internal LED lighting.
3. Equipped with internal heater to prevent condensation.
4. Pad lockable door handle
5. Manual ON/OFF/AUTO control switch per location.
6. Provide solid state logic to perform the control function identified herein.
   a. Provide temperatures and humidity sensors to control the heating elements, to prevent the energizing of the heating elements when the ambient temperature setting (adjustable) is above freezing or there is no precipitation. Indicate the temperature status and moisture status on the LCP separately.
   b. Separate on/off control for each turnout.
   c. Logic to stagger the start of the heating elements at a location to only one turnout of inrush current.
   d. Logic, rail temperature sensors, and wiring to turn off the elements of a turnout individually when the rail temperature is above trigger point (adjustable) and back on when the rail temperature drops back down. It is permissible, but not essential, that high and low rail temperature are independently adjustable but there shall be a minimum of 15 degrees Fahrenheit between the high and low points.
   e. Provide an indication on the signal house Local Control Panel (LCP) and to the LCC SCADA interface to indicate ON if any turnout’s heating elements are energized.
   f. Provide a LCP control to manually turn on the heating elements. When the LCP control OR the cabinet MANUAL ON/OFF/AUTO switch request ON it shall override the ambient temperature or moisture sensing inputs but shall not override the rail temperature sensing feature.

2.04 ACCESSORIES
A. Identification Letter-Numbers and Switch Point Position Letters: 3 inches high minimum, made of malleable cast metal, painted white or embossed or engraved on a metal plate.

PART 3 - EXECUTION
3.01 INSTALLATION
A. General:
   1. Provide power switch-and-lock movement layouts for each interlocked track switch and movable point frog at mainline locations as shown on Contract Drawings. Layouts shall include:
      a. Switch Machine.
      b. Gage plate extensions.
      c. Switch plinths:
         1) Concrete switch plinths in direct fixation track areas.
         2) Modifications or replacement of plinths in ballasted track areas.
d. Throw rod and all hardware.

e. Detector rod and all hardware.

f. Lock rod and all hardware.

g. Junction box with AREMA terminals.

h. Conduit from hand hole or junction box of Signals Communications duct bank provided by Civil Contractor.

i. All other hardware and adjustments to provide a working switch-and-lock movement.

2. Mount and adjust complete power switch-and-lock movement layout.

3. Paint equipment described in this Section in accordance with instructions in AREMA, Part 1.5.10.

B. Power Switch-and-Lock Movements:

1. Provide 15 W internal heaters in contact compartment and motor compartments.

2. Terminate wiring for heaters on mechanism terminal board.

3. Provide an internal wiring diagram protected by a plastic laminate and fasten it to underside of contact compartment cover.

4. Number wire terminal binding posts using stencils or other approved devices.

5. Verify that track switch layout is in accordance with dimensions indicated on Contract Drawings and as shown on approved installation drawings, prior to commencement of installation Work.

6. Provide two concrete pads to be cast in place for mounting each switch machine at direct fixation track locations.

7. In ballasted track, two long ties for mounting the power-switch-and-lock movement will be provided, in place, by others. Verify that the track switch layout is in accordance with the dimensions indicated on the Contract Drawings and as shown on the approved installation drawings, prior to commencement of installation Work.

8. Prior to mounting power switch-and-lock movements in ballasted track, verify that the switch head block ties (T1 and T2) are at right angles to the straight stock rail, in accordance with the approved installation drawing; condition the switch points to move without binding. Install the tie straps, as indicated on the Contract Drawings and in accordance with the approved installation drawing.

9. Wood Switch Ties: Dap and drill wood ties or shim above the trackwork contractor’s work to meet the requirements of this Specification. Whenever the Contractor drills, adzes, or daps wood ties, thoroughly saturate the cut surfaces with copper naphthanate, or other type of wood preservative, as approved by Sound Transit. Cutting or dapping shall not exceed two inches.

10. Concrete Switch Ties: Concrete switch ties provided by the Civil Contractor shall not be modified by the signal Contractor. If modification is essential at ballasted locations, remove existing, furnish, and install new concrete ties with the correct dap or mounting hardware, as approved by Sound Transit.
11. Provide a suitable NEMA 4X junction box suitable for direct fixation installations. For ballasted installations provide the switch machine pedestal mounted JB per the machine manufacturer’s recommendations.

12. Rods and Hardware: Provide a minimum of 8-inch threaded area on each rod to accommodate wide latitude in operating adjustments. A properly installed switch machine shall have a minimum of 1.5 inches of adjustment left for each direction.

13. Lubrication:
   a. Lubricate switch tie plates at lubricating points.
   b. Ensure that machined surfaces susceptible to rusting, both external and internal, are thoroughly coated with approved grease and that threaded portions of switch rods and nuts are similarly coated and protected.
   c. Periodically renew protective coating in accordance with Contractor’s Maintenance Plan, until such time as Sound Transit assumes responsibility for maintenance of equipment.
   d. Provide all manufacturer recommended lubricants and other consumables.

C. Cables:
   1. Dress underground cables terminating in switch junction box as specified in Section 34 42 08, External Signal Cable.
   2. Fan, tag, and terminate individual conductors. Tag nomenclature shall match function names and terminations per the signal control housing circuit plans.
   3. Provide junction box wiring between switch junction box and power switch-and-lock movement.
   4. Install cables in an appropriate length of approved conduit.

D. Identification:
   1. Provide number plates, affixed with rivets, for switch-and-lock movements.
   2. Letter switch machines with a number and “A”, “B”, “C”, etc. as indicated on Contract Drawings. Securely fasten with rivets identification letter centered on mechanism cover.
   3. Provide, for each layout, letters “N” and “R” and mounting hardware for the type of tie or plinth for purpose of identifying position of switch points.
   4. Place “N” on normally closed point sides as shown on Contract Drawings.
   5. Drill four holes in concrete plinths to receive fasteners suitable for securing letters.

E. Security:
   1. Ensure padlocks can be installed in the following locations:
      a. A signal padlock to restrict entry to inside of power switch-and-lock movement.
      b. A signal padlock to restrict entry to inside of motor compartment.
c. A signal padlock to restrict entry to inside of contact compartment.
d. A signal padlock to restrict entry to inside of hand crank selector lever, where applicable.
e. Switch padlocks to secure selector lever and hand crank lever.

F. Provide padlocks as specified in Section 34 42 97, Miscellaneous Hardware.

END OF SECTION
SECTION 34 42 18
AUDIO FREQUENCY TRACK CIRCUITS

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
   1. Design, procurement, and installation of audio frequency track circuits (AFTC).

1.02 REFERENCES
A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.
   1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
      a. C&S Part 8 - Communications and Signal Manual, Track Circuits

1.03 SUBMITTALS
A. Submit:
   1. Product Data: Description and/or catalog cut of proposed audio frequency track circuit to be furnished including proven equipment history.
   2. Preliminary Design of Track Circuit.
      a. Include track detection frequencies, speed command frequency tolerance, modulation rates and tolerances, description of operation, preliminary block diagrams, power output, shunting sensitivity, methods to provide speed commands in a typical interlocking, and to detect insulated joint failure.
      b. Include data on associated equipment that Contractor proposes to use such as loop drivers, couplers, or modules for direct speed command injection into single-rail track circuits.
      c. Provide data on resistance to EMI. Approval of EMC Control Plan submittal shall be a prerequisite for approval of this submittal.
   3. Track circuit calculations in accordance with Section 34 42 19, Power Frequency Track Circuits.
   4. Impedance Bond Installation Drawing.
      a. Submit typical impedance bond installation layouts, minimum 180 Days prior to installation.
      b. Include a typical impedance bond installation for each type of track fixation area.
c. Provide details of methods for installation of an impedance bond insulated joints, negative traction power return locations, and crossbonds.

d. Provide shop drawings showing details of protective ramps (covers).

e. Provide installation drawings on audio track circuit connections not involving impedance bonds such as terminating receiver location or direct injection speed command connections, including cable routing.

5. Speed Command Loops: Submit installation drawings of speed command loop installations, at least 180 Days prior to installation. Include hardware details, flexible conduit, wire size, routing at frogs and switch point areas, cross-section of installation, and data on components.

PART 2 - PRODUCTS

2.01 DESIGN REQUIREMENTS

A. Standards: In accordance with AREMA Communication and Signal Manual Sections 8.2 and 8.3.

B. Fail-Safe Design Requirement: design AFTC to incorporate fail-safe design principles. Ensure no single point failure of electronic components or maladjustments of user settings causes an unsafe condition.

C. Design track circuits compatible with traction power negative return. Track circuit operation shall not be affected by traction power return current imbalances.

D. Design track circuits not to be affected by LRV propulsion, traction systems or other parts of signal system.

E. Automatically restore track circuits to normal operation upon restoration of power after a power failure.

F. Design system to implement slow pick-up track repeater relays or their logic equivalents for track circuits.

G. Do not use track relay contacts in circuits affecting safety; use track repeater relay contacts in those cases.

H. Temperature Range: minus 40 degrees F to plus 160 degrees F.

2.02 MODULAR DESIGN

A. Each combination of track circuit modules shall stand alone, except for power supply(s) and logic.

B. Modular Replacement: design track circuits using a modular concept. Design track circuits to be maintainable by concepts of replacement and interchangeability in the field at lowest level replacement unit (PC board and relay). Design electronic shop subassemblies to be repairable at component level.

C. LED Indicators: For ease of maintenance, design circuitry to incorporate LED indicators. Indications include, but are not limited to receiver level detector output, code rate output, each amplifier output, and track relay status.
D. Design PCBs with test jacks at track circuit adjustment and normal field maintenance points.

E. Amplifiers breaking into spurious oscillations shall not result in an unsafe condition.

2.03 INDIVIDUAL MODULE REQUIREMENTS

A. Components: Individual carrier frequency oscillators, power amplifiers, line-coupling unit, receiver, and relay driver. Do not use carrier oscillators for more than one track circuit.

B. Dual Frequency: Design audio frequency track circuits to apply two modulated signals to the rails using:
   1. One frequency for train detection and broken rail detection.
   2. A separate 2340 Hz signal for train speed commands.

C. Transmitter:
   1. Design output amplifier of track transmitter such that voltage levels of 2340 Hz cab signal and track frequency can be adjusted independently.
   2. Power Amplifier: No variable level adjustment, amplifies carrier’s power level as necessary to feed track circuit.
   3. Transmitter Level Adjustment Acceptable Techniques:
      a. Jumper connections on power amplifier plugboard external to printed circuit board on which power amplifier is located. Or
      b. Adjust taps on a fixed resistor external to printed circuit boards on which transmitter electronics are located.
   4. Transmitter Rail Current Output: 0.25 amp minimum with a 0.2-ohm shunt placed at entering end of track circuit.

D. Receiver Filter:
   1. Type: Bandpass filter tuned to carrier frequency of track circuit.
   2. Train Detection Carrier Frequency.
      a. No more than 3 dB down at plus or minus 2.5 percent.
      b. Minimum 20 dB down at plus or minus 8 percent.
   3. Minimum 60 dB down for other train detection frequencies, their harmonic frequencies, and their beat frequencies.
   4. Shorting or opening of element or component within the filter shall either:
      a. Not change pass band, non-ringing, and attenuation characteristics of filter.
      b. Attenuate output of filter so that associated track relay will drop or remain down.
   5. Adjustable Elements: None.

E. Receiver Amplifier: Adjustable tuning control, receiver sensitivity may be varied to enable setting of track circuit pre-shunt distance.
F. Design receiver section components to prevent an unsafe condition in the event of component failure.

G. Relay Driver: Energizes track relay when a carrier signal is being received, prevents relay from picking up due to self-oscillations of an electronic circuit, includes no adjustments.

H. Direct output from track module to signal vital processor (SVP) may be used in place of a track relay.

I. Audio Frequency Track Circuit Track Relay: DC biased neutral relay in accordance with Section 34 42 58, Relays.

J. Relay Drop Away Time: Maximum 1.0 second from time of track shunt until back contacts make.

K. Line Coupling Unit: Matches output of power amplifier to line circuit going to impedance bond, permits both transmission to bond and reception from an adjacent track circuit bond, no adjustable elements.

L. Line Circuit Cable: Twisted pair cable, shielded as required by Contractor's design, in accordance with Section 34 42 08, External Signal Cable, and Section 34 42 55, Internal Signal Cable.

2.04 TRAIN DETECTION

A. Design system to detect trains using audio frequency track circuits using train detection frequencies.

B. Track Circuit Receiver: Declares non-occupied condition (energized) only when a carrier signal is being received that is modulated on-off at same rate as track transmitter for that circuit with correct duty cycle and of proper power level.

C. Track circuit receiver shall not permit energized condition until at least three complete valid code periods have been detected.

D. Except in areas covered by single-rail track circuits, design of AFTC track circuit shall provide broken rail protection.

E. Train Detection Frequencies:

1. Characteristic: Modulated at a constant code rate(s), distinct from speed command code rates.

2. Amount: Minimum of eight discrete frequencies, minimum of four applied to a specific track.

3. Multiple Track Territory: Use a unique grouping of four frequencies for each track.

4. Minimum Separation: Use three frequencies before repeating initial frequency.

5. Provide maximum physical separation between track circuits using the same frequencies.

6. Select track circuit detection frequencies and modulation rates that avoid EMI problems.

7. Overrun Protection: In the event that a train overrun a stop signal, it shall not receive a permissive cab code that was intended for another train. Arrange track circuits and cab loops to ensure overrun protection.
F. Shunting Requirements:

1. Shunt Resistance: 0.2 ohm shall indicate train occupancy.
2. Defective insulated joints shall indicate train occupancy.
3. Document post shunt. RE approval is required to confirm design headway and operation is not impacted by post shunt greater than 35 feet.
4. Ensure track circuits detect a train approaching a block boundary when front most axel is between 9 feet and 35 feet before block boundary at those locations where block boundary is not defined by insulated joints.

2.05 SPEED COMMANDS

A. Design cab signal module to apply a modulated code rates when vital logic external to the module determines that minimum safety requirements for transmitting a speed command are satisfied.

B. Design system to transmit cab codes to trains running in either normal or reverse direction. Design system such that cab signal is applied to the rail a maximum of one track circuit in advance of approaching train.

C. Design system to pre-energize cab codes in loops prior to the arrival of a train when the section of track that the loop is transmitting cab codes within is preceded by insulated joints.

D. Cab Signal Carrier Frequency: 2340 Hz plus or minus 11 Hz.

E. Signal Strength: Design cab signal strength to provide reliable operation when a 0.20 ohm shunt is applied anywhere in the track circuit. Generate calculations based on approved block design. Nominal cab rate at entering end shall be 250 milliamp

F. Modulation Rates: Design cab signal module to provide modulated code rates as shown in Table 1.

G. 25 MPH Street Running Code: Selected with second 6.25 Hz set of pulses after a one second delay from the start of the first set of 6.25 Hz pulses which will cause a 35 mph street running mode.

H. Duty Cycle Tolerance: +/-1%,

1. (VP): at the vital processor driving the cab frequency generator.
2. (IB): measured in the rails, induced by the Impedance Bond.
### TABLE 1

<table>
<thead>
<tr>
<th>Speed Command</th>
<th>Frequency (Hz)</th>
<th>Period (ms)</th>
<th>Duty Cycle (VP)</th>
<th>Duty Cycle (IB)</th>
<th>Tolerance (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street Running – 25mph</td>
<td>6.25 2nd Pulse</td>
<td>160</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
<tr>
<td>Street Running – 35mph</td>
<td>6.25</td>
<td>160</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
<tr>
<td>0 MPH</td>
<td>No Code</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 MPH</td>
<td>6.94</td>
<td>144</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
<tr>
<td>20 MPH</td>
<td>7.81</td>
<td>128</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
<tr>
<td>30 MPH</td>
<td>8.93</td>
<td>112</td>
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<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
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<td>35 MPH</td>
<td>10.42</td>
<td>96</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
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<td>40 MPH</td>
<td>12.5</td>
<td>80</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
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<td>15.63</td>
<td>64</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
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<td>55 MPH</td>
<td>20.83</td>
<td>48</td>
<td>50%</td>
<td>35-65%</td>
<td>plus or minus 1</td>
</tr>
</tbody>
</table>

I. Code Rate Selection:

1. Design code rate selection logic using either vital relay or solid-state logic to select correct modulation rate in accordance with approved control line design.

2. Failures of equipment, within logic or associated track circuit modules, shall cause system to revert to either a safer modulation rate or to transmit no speed code.

3. Design system to allow temporary adjustment to speed command lower than maximum allowed by its governing control line via a speed command selection panel.

4. Ensure speed commands shown on Contractor’s control line design drawings are maximum that can be selected.

2.06 SPEED COMMAND LOOPS

A. Wire loops of #8 AWG, minimum wire size clipped to the rail, rail fasteners, or adjacent ties as provides the best signal to the LRV receiver coils.

B. Transmitters.

1. Speed command transmitter and transformer: Capable of providing signal strength of greater than 600 milliamps minimum in a wire loop. Initial setting shall be 600 milliamps for all cab loops.

2. Provide ability to perform adjustments in module and transformer.
2.07 INTERLOCKING TRACK CIRCUITS

A. Track circuits within interlockings are either single or double rail, as shown on Contract Drawings.

B. Provide both straight and crossover portions of interlocking with train detection and bi-directional speed commands.

C. Interlocking track circuit design shall satisfy the following requirements:
   1. Rail connections of track circuit equipment as well as bonding, loops, balance rails, and by-pass cables shall provide for the smallest possible dead areas where carborne coils cannot receive speed commands.
   2. Speed commands supplied by a bond, or loop for a specific route, shall not be detectable in track circuits outside the interlocking or on a parallel route.
   3. Design layout to provide maximum possible broken rail protection consistent with other requirements.
   4. If a train passes a signal displaying a stop aspect, no cab signal shall be present in circuit track immediately beyond signal.

D. Insulated Joint Failure Detection: Shorting of an insulated joint shall cause one or more track circuits, defined by the joint, to indicate occupancy. Insulated joint failure detection shall not be diminished by special trackwork bonding, negative return connections, or crossbonding.

E. Traction Power Return: Design interlocking and equipment to permit traction power to return through interlocking area and provide at least one negative return rail throughout the interlocking. Ensure current imbalances caused by trains do not disrupt system operation.

F. Insulated Joint Location: Insulated joints shown on Contract Drawings are furnished by the Civil Contractors. Additional insulated joints required by Contractor’s design shall be installed only with Sound Transit’s approval and at Contractor’s expense.

2.08 IMPEDANCE BONDS – AUDIO FREQUENCY TRACK CIRCUITS

A. Standards: In accordance with AREMA Communication and Signal Manual Sections 8.4.5, 8.4.6, 8.4.8, and 8.4.9.

B. Design impedance bond installations to perform the following functions:
   1. Couple train detection and speed limit signals to running rails.
   2. Receive train detection signals from running rails.
   3. Carry propulsion return current from running rails to track crossbonding connections, cables, or substation return, via center tap connections.
   4. Carry propulsion return current around insulated joints in running rails, via center-tap connections.
   5. Provide connections to allow for cross bonding as shown on Contract Drawings.

C. Electrical Characteristics.
   1. Design impedance bond track winding, and associated cabling and connections, to carry a minimum of 2,000 A per rail continuously.
2. Traction Current Imbalance: Operates with minimum 12 percent.
3. Ripple Current Imbalance: Operates with minimum 30 percent.
4. Dc Resistance Between Track Winding Terminal Lugs: Maximum 2.5x10^{-5} ohm.

D. Cable Connections.
1. Track Winding Lug: Accept two 250 kcmil cables.
2. Track Connection Cable: 250 kcmil insulated, stranded copper cable, 30 feet maximum length.
3. Side lead cables to be of equal length plus or minus one foot.

E. Center Tap.
1. Center Tap Lug: Accept up to four 500 kcmil cables.
2. Capable of terminating cross-bonding cables, a neutral cable to another impedance bond on same track at insulated joints, and terminating dc negative returns.
3. Sufficient size to accommodate terminations required, and for maximum current that may be encountered.

F. Size impedance bonds, tuning units, and protective ramps to facilitate mounting between running rails.

G. Protective Ramps: Provide ¼ inch steel plate, designed to protect bond and tuning unit from physical damage for all impedance bonds mounted between the rails.

2.09 TRACK CIRCUIT CALCULATIONS
A. Prepare calculations for adjusting each track circuit including, but not limited to, power and sensitivity settings, and cab signal strength similar to those provided for power frequency track circuits.
B. Forms with these calculations and for recording these adjustments in the field shall be prepared by Contractor and submitted to Sound Transit for approval.
C. Calculations shall include operating margins to accommodate EMI.
D. Track circuits shall be adjusted in accordance with appropriate calculations and readings recorded on the appropriate form.
E. Track circuit calculations shall assume a power line voltage regulation of plus or minus 10 percent.
F. Calculations shall assume a normal ballast resistance variation of between 5 Ohms per 1,000 feet (1.5 Ohm/1,000 feet in paved track) and an infinite ballast resistance.
G. Use these calculations to check locations of cross bonds.

2.10 AUDIO FREQUENCY OVERLAY TRACK CIRCUITS
A. Provide overlay track circuits designed to work with 100 Hz Power Frequency Track Circuits and with dc Tractive Electrification.
B. Provide modulated audio frequency overlay track circuits with at least one vital output capable of driving a signal relay.

C. Provide overlay track circuits that do not require additional insulated joints to operate.

D. Provide all required tuned coupling units to create low impedance for the track circuit frequency and high impedance for all other frequencies at or near the track connection.

E. Connect the overlay track circuit directly to the rails with a minimum of No. 6 AWG super flex cable with an approved bolted connection.

F. Rotate the frequency and modulation so that no overlay track circuit adversely affects any other overlay track circuit.

PART 3 - EXECUTION

3.01 GENERAL

A. Design and provide equipment necessary to complete a functioning audio frequency track circuit train detection and cab signaling system.

B. Provide wayside AF track circuits compatible with existing LRV cab decoding. Sound Transit will arrange a test track in the Yard or other location where Contractor can demonstrate compatibility to Sound Transit.

C. Design and provide additional bonding cables for traction power or additional coupling equipment.

D. Main Line Track: Design and provide jointless, audio frequency track circuits as shown on Contractor’s approved block design. Provide back to back impedance bonds where insulated joints are shown on Contract Drawings.

E. Special Trackwork: Provide audio frequency track circuits as shown on Contractor’s approved interlocking design. Provide cab signals through alternative means such as direct injection or cab loops when power frequency track circuits and over run protection require.

F. Loss of Shunt Timers:
   1. Provide all track circuits within an interlocking, bound by entrance and exit signals, with a 5 second loss of shunt timer to hold the route stick and detector locking.
   2. Provide all mainline track circuits between interlockings with a 2 second loss of shunt timer for use in vital functions such as route locking, grade crossing calls, cab signal speed logic, and others.
   3. Provide a 5 second loss of shunt timer for use in traffic direction locking.

3.02 RACK MOUNTING

A. Mount track modules on 19-inch racks with sufficient spacing to permit easy removal and adequate cooling, without forced air cooling.

B. Ground chassis of each track module to rack with a separate wire.
3.03 IMPEDANCE BONDS

A. Provide one line circuit cable to each impedance bond. Provide a tuning unit with each track circuit bond location.

B. Location.
   1. Provide at locations shown on Contract Drawings.
   2. Mount impedance bonds between the rails wherever possible.
   3. Provide protective ramps (covers) to be installed on top of bonds.
   4. Do not install impedance bonds where they interfere with cleaning of drains or the use of crosswalks.
   5. Where adjustment of impedance bond location would create or increase a speed command dead space, notify Sound Transit.
   6. If impedance bonds cannot be located between the rails, they may be installed on the wayside upon approval of Sound Transit.

C. Mounting: Mount impedance bond and its associated protective cover a minimum of ½ inch below top of rail. Mount impedance bond a minimum of ½ inch above invert. Mount with anchor bolts in accordance with Section 34 42 97, Miscellaneous Hardware.

D. Impedance bond rail connections: Provide one center tap terminal lug on each impedance bond. Provide two track connection terminal lugs on each impedance bond. Provide two track connection cables from impedance bond to each rail. Connections the track shall be Cembre, ERICO, or similar bolted connection. See section 34 42 30 Signals Rail Bonding for detail on how to make connections to the rail.

E. Provide watertight connectors for external connections to tuning unit and connections to impedance bond.

F. Tuning Unit.
   1. Tune units shall match output of amplifiers to line circuit to compensate for cable lengths.
   2. Locate tuning unit at bond or with track circuit module.
   3. Tune unit for high impedance for cab signal and track frequencies transmitted or received from this bond. Reduce rail-to-rail impedance for other frequencies sufficient to ensure system safety.
   4. Rail-to-rail high impedance requirement does not apply for track circuit boundaries defined by equipment other than bonds, such as B points (high definition loops), or special tuning required in accordance with Contractor’s approved interlocking layout. Design system to provide an equivalent level of safety at these locations.

3.04 SPEED COMMAND LOOPS

A. Install and fasten wire loops so that wire is not damaged by fastener and is able to produce a proper signal for carborne cab signal units.

B. Transpositions: Make transpositions of loop from one rail to the other as necessary to keep a signal from being induced in the rail. Provide documentation and calculations supporting transposition requirements.
C. Routing: Fasten loop wire to rail with rail clips or clamp conduit to invert or plinths. Provide non-metallic supports over gaps or drains, where necessary, such that tripping hazard and potential damage to cable is reduced or eliminated.

3.05 AUDIO FREQUENCY OVERLAY TRACK CIRCUITS

A. Location

1. Provide at the locations shown on the Contract Drawings.

2. Install tuned coupler units in the impedance bond cover enclosures, track boxes, hand holes, or provide OCS pole mounted enclosures.

3. Provide overlay track circuit modules in the closest crossing house to the overlay track circuit connection point.

END OF SECTION
SECTION 34 42 19
POWER FREQUENCY TRACK CIRCUITS

PART 1 – GENERAL

1.01 SUMMARY

A. Section includes:

1. Design, procurement, installation, and testing of power frequency track circuits.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

   a. Part 8 - Track Circuits
   b. Part 11 - Circuit Protection
   c. Part 14.2 - Electrical Devices

1.03 SUBMITTALS

A. Submit:

1. Product Data: Description and catalog cut of proposed track circuits to be furnished including:
   a. Proven equipment history of 5 years successful service in North America.
   b. Circuit drawing and description identifying that performance requirements have been met.
   c. Parts list.
   d. Component drawings and data.

2. Track Circuit Calculations.

3. Power Frequency Track Circuit Installation Drawings: Identify materials and methods to be used for installation. Submit product data, such as catalog cuts and installation procedures, as required to fully describe each element of installation.
PART 2 - PRODUCTS

2.01 DESIGN REQUIREMENTS

A. Failsafe Design Requirement: Use fail-safe design principles in design of track circuit components. Failure of component or maladjustment of track circuit shall not cause an unsafe condition.

B. A shunt of 0.2 ohm between rails at any location within a track circuit shall cause that track circuit to indicate LRV occupancy.

C. Design track circuits and track circuit arrangement to be compatible with traction power negative return. Track circuit operation shall not be affected by traction power return current imbalances.

D. Restoration of power after a power failure shall automatically restore track circuits to normal operation.

E. Reset of de-energized track circuits shall not be based on adjacent track circuit occupancy.

F. No center-fed power frequency track circuits allowed.

G. Design power frequency track circuits such that no components are shared except for primary of transformer.

H. Design system with adjustable resistors to allow shunting sensitivity adjustment in conjunction with transformer taps.

I. Functional Temperature Range: Minus 40 degrees F to plus 160 degrees F.

J. Track Circuit Configuration:
   1. Single-rail in special trackwork.
   2. Double-rail if required by the Contract Documents.


L. Track Circuit Frequency: 100 Hz.

2.02 ELECTRICAL CONNECTIONS

A. Fuses:
   1. Design single-rail track circuit connections (track feeds and track relays) with protective fuses.
      a. Fuse on Relay End: 10 A.
      b. Fuse on Transformer End: 20 A.
   2. Design double-rail track circuit connections (track feeds and track relays) with fuses.
      a. Fuse on Relay End: 6A.
      b. Fuse on Transformer End: 20A.
B. Lightning Protection: In accordance with AREMA Communications and Signals Manual, Part 11.3.1.


2.03 TRANSFORMERS

A. Transformer Power Frequency: 100 Hz.


C. Primary Winding: 120 V with a 13 percent tap to compensate for reduced voltage.

D. Design number and voltage of secondary windings compatible with application needs.

E. Design voltage taps that provide for suitable track circuit adjustment.

F. Mounting: Suitable for rack mounting.

G. Include balancing impedance or blocking transformer for each single-rail track circuit, to minimize effects of DC propulsion current on track circuit.

2.04 IMPEDANCE BONDS – POWER FREQUENCY TRACK CIRCUITS

A. Impedance bonds shall be installed where required and shall comply with AREMA Communication and Signals, Part 8.4.5. Impedance bonds shall meet the following requirements:

1. Bonds shall be rated at 1000 amps DC (minimum) per rail for two hours; rated at 2,000 amps DC, per rail, for one minute (nominal 1,000 amp rating).

2. Rail connections shall be stranded copper, two 250 kcmil insulated cables and arranged for independent Cembre, ERICO, or similar bolting to rail of each cable. Two cables per rail on each side of each insulated joint shall be installed. The cable insulation shall not be within 12” of rail welds. Connections shall be centered within +/- ½” of the neutral axis of the rail.

3. Center-tap connections from each TES substation to the impedance bond shall be capable of accepting four 500 kcmil cable lugs with bolted connections. Quantities of 500 kcmil cables installed connecting to the center tap shall be as specified for audio frequency impedance bonds. Impedance bond connections to the rail shall be capable of accepting two 500 kcmil cable lugs with bolted connections at each end of the bond.

4. Bond windings and magnetic circuit shall be encapsulated to be watertight and covered on all four sides by a wrap-around cover. Covers shall be malleable iron.

5. Bonds shall be supplied, complete with cooling medium, ready for installation.


7. Impedance bonds shall be designed for use with 100 Hz track circuit frequencies. Tuned bonds shall not be used.

8. In areas where concrete cross ties are used and an impedance bond is required, mount bonds to concrete ties, using brackets and metal straps such that no drilling of ties is required, or mount outside the rails adjacent to the track.
2.05 RELAYS
A. Type: Vital two-element, phase-selective, plug-in, vane relays suitable for operation on 100 Hz track circuits.
B. Local Element Voltage: 120 V nominal.
C. See Section 34 42 58, Relays, for additional requirements.

2.06 TRACK CIRCUIT CALCULATIONS.
A. Calculate settings for each track circuit, including feed voltages, transformer tap settings, and resistor settings demonstrating that the 0.2 ohm shunting requirement is satisfied.
B. Prepare forms with these calculations and for recording these adjustments in the field.
C. Assume a power line voltage regulation of plus or minus 10 percent.

2.07 EMI MITIGATION
A. Track circuits will be exposed to several sources of electromagnetic interference including, but not limited to, rectified traction power voltage and LRVs themselves which will use ac propulsion equipment.
B. Design system, as installed, to function properly in this environment.
C. Design protection to prevent unsafe conditions and damage to equipment under fault and surge conditions.

PART 3 - EXECUTION
3.01 GENERAL
A. Provide power frequency track circuits at special trackwork and street running areas on mainline as shown on Contract Drawings.
B. Adjust track circuits in accordance with approved calculations, and record readings on approved form.
C. Install impedance bonds in accordance with approved installation drawings.
D. Cable Connections: Connect cabling to the rail with Cembre, ERICO, or similar bolted rail connections or directly to the impedance bond.
E. Cable Size: No. 6 AWG minimum size twisted pair wire. Route cable in conduit.
F. Wire from signal housing and from rail shall terminate at a field junction box in the vicinity of the rail connection which shall permit rail isolation.

G. Wiring,
   1. Provide fuses with a minimum rating as identified in 1.02 of this section in series with wires connecting to the rails for power frequency track circuits.
   2. Provide insulated copper, #14 AWG (minimum), for wires and cables in signal equipment rooms.
   3. Use twisted pairs for track circuit wires on power frequency track circuits.
4. Dress wire neatly and firmly, attach to plinths, and keep clear of plinth and rail attachment devices when passing beneath a rail.

5. Run wires and cables that attach to rails along the side of plinths just below top surface. Provide rigid or flexible conduit or hose protection clamped to the concrete back to the track connection junction box.

6. For ballast installations track connection cables shall install in the ballast shall install in conduit to a minimum depth of 1 inch below bottom of tie.

7. Fasten wires and cables that attach to the rails to web of rail using rail clips before coming off rail to plinth or ballast.

END OF SECTION
SECTION 34 42 20
TRAIN-TO-WAYSIDE COMMUNICATIONS SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:

1. Design and installation of the Train-to-Wayside Communications (TWC) System.

1.02 SUBMITTALS
A. Submit:

1. Product Data:
a. Description and/or catalog cut, including proven equipment history of the following:

   1) TWC interrogators.
   2) Interrogator lead cable.
   3) Loop converter.

2. Shop Drawings:
   a. Detailed, scaled mechanical layout drawings suitable for manufacturing including parts and material list for loop antennas.
   b. TWC installation adjustment procedures.

3. TWC Loops: Detailed, scaled mechanical layout drawings suitable for manufacturing including parts and material list for loop antennas. TWC installation adjustment procedures.

B. Closeout Submittals:

1. Operation and Maintenance Manuals:
   a. Show as-installed and tested configuration of each TWC interrogator including TWC output masking as part of the design, as-shipped, and as-built book of plans for each location.
   b. Provide copies of any software associated with the interrogator that is used in programming or maintenance.
   c. Show model numbers and location of every electronic rack, electronic circuit card, and power supply.
   d. Show as-installed location and size of each TWC loop.
e. Provide a description of TWC system and a description of each printed circuit card and electronic module complete with part numbers, theory of operation, and test requirements.

PART 2 - PRODUCTS

2.01 DESIGN REQUIREMENTS.

A. Basic functional requirement for TWC system involves calling routes at interlockings. Train operator shall not be able to call a route into reverse running traffic direction.

B. Design system such that current in each wayside TWC loop generates a Radio Frequency Signal detected by car-carried TWC transponder located at each end of each LRV.

C. Upon receipt of wayside TWC interrogation signal, car-carried transponder shall transmit a 19-bit data message back to wayside loop.

D. Design wayside TWC equipment to function with carborne TWC equipment currently in use on Sound Transit system.

E. List of TWC Destination Codes shall be confirmed with Sound Transit prior to masking interrogators.

2.02 CARBORNE EQUIPMENT

A. Manufacturer/Product: TWC System: Phillips VETAG type by Hanning and Kahl, Irwin Industries, or approved equal.

B. LRVs are equipped with TWC transponders at both ends on center line of car body, approximately 5 feet from end of coupler.

C. TWC system uses a wayside interrogator to excite a wayside loop antenna with approximately 0.1 A, at frequencies between 90 kHz and 100 kHz.

D. Transmission from car-carried transponder is between 90 kHz and 100 kHz.

2.03 INTERROGATORS

A. Check received data messages for presence of proper start and stop codes. Validate data messages only after two identical successive data messages have been received. After validation, generate a strobe signal to enable transfer of data to an output buffer.

B. Trains traveling at track speed (the posted speed limit) shall be able to transmit four complete data messages per antenna lobe, even in the event that other transponders are over other loops controlled by the same interrogator. Assume zero speed for loops within the platform.

C. Wayside control equipment shall query a transponder, and successfully receive and decode data messages from that transponder. Loop antenna shall activate and receive data messages from transponders within range. Transmit 19-bit output plus loop identifier bits to TCS equipment in the signal room.

D. Interrogator shall be convertible to bi-directional communications by adding modules or printed circuit cards.

E. Interrogator shall provide automatic tuning of wayside loops without the use of passive tuning devices at the loop.
F. Interface circuitry, raceway, and cabling shall meet functional requirements. Electronic circuitry, except power supplies shall be on removable printed-circuit cards. No more than four loops may be controlled from a single interrogator.

G. Lifespan: Design for a 30-year life in wet and dry applications.

H. TCS Connection: RS232 serial data.

I. Loop to Interrogator Distance: 1,200 feet maximum with minimum #14AWG shielded cable and 2,130 feet maximum with 75 ohm coaxial cable.

J. Loop Antenna Receive Frequency: 90 kHz to 100 kHz.

K. Transmission Speed: 2 kbits/s minimum.

L. Circuit Cards.
   1. Design data from output buffer to be transmitted to application circuit cards.
   2. Design circuit cards with relay contact closure(s) to enable route request Signal Vital Processor (SVP) logic to act upon messages transmitted from the train.
   3. Contacts: Rated 0-24 Vdc at 2.0 A.
   4. Application Outputs: In accordance with Contract Drawings and described herein.

M. Expandability.
   1. TWC equipment shall be capable of being expanded to include additional outputs.
   2. Each interrogator rack shall contain sufficient backplane wiring, power supply capacity, and spare printed-circuit board socket capacity to allow for the following outputs in addition to outputs required for the present system:
      a. Buffered parallel output suitable for direct connection to a microcomputer driven electronic passenger information display on the wayside.
      b. Buffered relay output to call additional routes.
   3. In the event that a 19-inch interrogator rack controls more than one loop antenna, that interrogator rack shall contain sufficient capacity to provide additional outputs, described above, for each loop.
   4. Bi-directional communications. The Wayside TWC system shall be convertible to bi-directional communications using only modifications to the interrogator.

N. Leads: Provide leads continuous from interrogator terminal strip to loop converter located at the TWC loop. Construct in accordance with manufacturer's recommendations. Include amplifiers, loop converter and junction boxes. Minimum 12 AWG stranded copper conductor.

2.04 PRE-FABRICATED TWC LOOPS

A. Fabricate loops in accordance with approved detailed mechanical layout drawing. Additional loop antenna design criteria shown in details on Contract Drawings.

B. Mount TWC loops using anchor bolts or all-thread such that height may be adjusted up to one inch below top of rail and that pre-fabricated loop would provide a steady platform with a 250 pound load placed on it.
2.05 EMBEDDED TWC LOOPS
A. One continuous length of wire out and back from loop converter.
B. Loop sealant: Sika Repair SHA, Sika Top 122 Plus, or approved equal.

2.06 TWC DATA REQUIREMENTS
A. Design wayside TWC equipment to receive and process a 19-bit data message from carborne transponders.
B. Design wayside interrogators to process the following information from LRVs via wayside loop antennas:
   1. Active Cab:
      a. Train Number (00-99) -- 7 bits.
      b. Destination Number (00-99) -- 7 bits.
      c. Stationary Pre-empt / CALL button in cab -- 1 bit.
      d. Cancel (Route) button in cab -- 1 bit.
      e. Switch Call (Left or Right) button in cab -- 2 bits.
      f. Active Cab (on for active cab) -- 1 bit.
   2. Intermediate (rear-end, inactive) Cabs (for multiple-unit consists only):
      a. Car Number (000-999) -- 10 bits.
      b. Active Cab (off for intermediate cab) -- 1 bit.
      c. End-of-train (off for intermediate cab) -- 1 bit.
      d. Spare -- 7 bits.
   3. Trailing (rear-end, end-of-train, inactive) cab:
      a. Car Number (000-999) -- 10 bits.
      b. Active Cab (off for trailing cab) -- 1 bit.
      c. End-of-train (on for trailing cab) -- 1 bit.
      d. Spare -- 7 bits.

2.07 LOOP CONVERTER
A. Loop converter tuning device.
   1. Tune TWC loop automatically or at interrogator with manual selection.
   2. Allow for bi-directional communications.
   3. Loop converter shall not require passive component tuning at TWC loop.
### Table 1

**Data Code Format (Truth Table)**

**Train/Wayside Communication System**

<table>
<thead>
<tr>
<th>Transponder Data Bits - Lead Cab</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>16</th>
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<th>19</th>
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<tr>
<td><strong>Binary Weight</strong></td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>16</td>
<td>32</td>
<td>64</td>
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<td>1</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>16</td>
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<td><strong>Lead Cab</strong></td>
<td>LC</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>D</td>
<td>P</td>
<td>CA</td>
<td>T</td>
<td>T</td>
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<td>S</td>
<td>S</td>
<td>T</td>
<td></td>
<td></td>
</tr>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<td>X</td>
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<tr>
<td><strong>Pre-empt (&quot;Call&quot;)</strong></td>
<td>1</td>
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<table>
<thead>
<tr>
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<th>2</th>
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<th>4</th>
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<td><strong>Binary Weight</strong></td>
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<td>2</td>
<td>4</td>
<td>8</td>
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<td>32</td>
<td>64</td>
<td>AA</td>
<td>BB</td>
<td>C</td>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td><strong>Non-Lead Cab</strong></td>
<td>NL</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
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<td>RC</td>
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<td>X</td>
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<td><strong>Intermediate Cab</strong></td>
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<tr>
<td><strong>Rear End-of-Train</strong></td>
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</tr>
</tbody>
</table>

**Legend**

- **AA** = Binary 128
- **BB** = Binary 256
- **CC** = Binary 512
- **C** = Car Number (0 through 999)
- **RC** = Rear Cab (Signal from Tail Lamps)
- **LC** = Lead Cab (Front End)
- **NL** = Non-Lead Cab (Intermediate Cab or Trailing Cab)
- **P** = Pre-empt or "CALL"
- **CAN** = Cancel
- **D** = Destination Number (0 through 99) See Table 2 for list of destination codes.
- **S** = Track Switch Control (Left or Right)
- **SP** = Spare
- **T** = Train Number (00 through 99)
- **X** = High or Low Logic Level (Left LSB, Right MSB)
- **1** = High Logic Level
- **0** = Low Logic Level
### TABLE 2

Sound Transit - TWC Destination Codes (to be confirmed prior to final design)

<table>
<thead>
<tr>
<th>CODE</th>
<th>DESTINATION</th>
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<tbody>
<tr>
<td>00</td>
<td>Turnback Area</td>
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<td>01</td>
<td>Storage Track 1</td>
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<td>02</td>
<td>Storage Track 2</td>
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<td>03</td>
<td>Storage Track 3</td>
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<td>Storage Track 4</td>
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<td>12</td>
<td>Storage Track 12</td>
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<tr>
<td>13</td>
<td>Storage Track 13</td>
</tr>
<tr>
<td>14</td>
<td>Run-Around Track East Side</td>
</tr>
<tr>
<td>15</td>
<td>YC Holding Track East Side</td>
</tr>
<tr>
<td>16</td>
<td>YA –YC Connection Track</td>
</tr>
<tr>
<td>17</td>
<td>YC Holding Track East Side (normal approach)</td>
</tr>
<tr>
<td>18</td>
<td>Approach Track to Destination 15</td>
</tr>
<tr>
<td>19</td>
<td>Spare</td>
</tr>
<tr>
<td>20</td>
<td>Run-Around Track West Side</td>
</tr>
<tr>
<td>21</td>
<td>Shop Track 1</td>
</tr>
<tr>
<td>22</td>
<td>Shop Track 2</td>
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<td>23</td>
<td>Shop Track 3</td>
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<td>24</td>
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<td>26</td>
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<tr>
<td>27</td>
<td>Shop Track 7</td>
</tr>
<tr>
<td>28</td>
<td>Shop Track 8</td>
</tr>
<tr>
<td>29</td>
<td>Yard Operations, Car Wash; Mainline, WLS SB Platform Turnback</td>
</tr>
<tr>
<td>30</td>
<td>YA Track</td>
</tr>
<tr>
<td>31</td>
<td>YC Track</td>
</tr>
<tr>
<td>32</td>
<td>Pine Street Interlocking</td>
</tr>
<tr>
<td>33</td>
<td>Royal Brougham Pocket</td>
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<tr>
<td>34</td>
<td>University of Washington Terminal</td>
</tr>
<tr>
<td>35</td>
<td>Northgate Terminal</td>
</tr>
<tr>
<td>36</td>
<td>Northgate Pocket</td>
</tr>
<tr>
<td>37</td>
<td>Lynwood Terminal</td>
</tr>
<tr>
<td>38-39</td>
<td>Spare</td>
</tr>
<tr>
<td>40</td>
<td>Rainier Pocket</td>
</tr>
</tbody>
</table>
PART 3 - EXECUTION

3.01 INTERROGATOR
   A. Mount interrogator equipment in racks in signal equipment rooms. Provide inputs to non-vital portion of SVP.

3.02 TWC LOOP INSTALLATION
   A. Provide as shown on Contract Drawings. Provide cabling, loop converter, and junction boxes necessary to accomplish the required functions.
   B. Install between the rails from 0 to 1.5 inches below top of rail. Connect to TWC interrogator by interrogator lead and loop converter.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. Section includes:
      1. Procurement and installation of bonding of main line and special trackwork rails for traction negative return and signal track circuits, crossbonding, and rail connections at locations shown on Contract Drawings.

1.02 SUBMITTALS
   A. Submit:
      1. Product Data: Description and catalog cut of proposed components and hardware items to be furnished including proven equipment history including the following:
         a. Proposed bonds for each size cable to be used identifying part number, wire size, stranding, and terminations.
         b. Proposed drill motors and cutting head.
         c. Proposed bushings.
         d. Proposed process and tool to install bushings.
         e. All lugs and other hardware.
      2. Test and Evaluation Reports: Rail bonding testing documents.
         a. Test Procedures and Test Results for each field test.
         b. Certified Test Report for field testing.

PART 2 - PRODUCTS

2.01 CABLE
   A. Power Bond Cable: Two 250 kcmil cables, two 500 kcmil cables, extra flexible stranding designed for rail bonding.
   B. Audio Frequency Overlay Track Circuit: #6 AWG cable to be used from coupler unit to rail.

2.02 DRILL MOTOR, CUTTING HEADS, AND BUSHING PRESS
   A. Cembre, ERICO, or approved equal.
   B. Drill Motor and Cutting Heads: Capable of cutting through the rail web without causing damage to the rail.
C. Bushing Press: Capable of extruding a copper bushing into the hole in the web of the rail.

2.03 BUSHINGS, CABLE LUGS AND OTHER HARDWARE

A. Bushings: Copper bushing capable of being extrude in the hole in the rail web such that the copper material flows into the wall or the hole, compensating for variations in the hole size and filling any voids and uneven surfaces.

B. Cable Lugs: Tin plated copper cable lugs capable of being compression clamped to all proposed cable sizes.

C. Hardware: All bolts, washers, lock nuts, and other hardware required to securely fasten the lug to the rail bushing.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install bonding in accordance with approved procedures, installation drawings, and in accordance with manufacturer's recommendations.

B. Maintain running rail electrical isolation from ground.

3.02 RAIL CONNECTIONS

A. Bolt bonds to rail.

B. Test each bolted connection in accordance with manufacturer's manual on installation.

C. Replace defective bolted connections.

D. Stagger at intervals of not less than 8 inches on centerline.

E. Center bolted connections to web of rail within plus or minus 1/4 inch of neutral axis.

F. Provide sufficient slack to accommodate rail movement due to expansion and contraction.

G. Prep the web of the rail in accordance with manufacturer's installation procedure.

H. Replacement connections shall be relocated, a minimum of 4 inches on centerline, from their original locations.

3.03 FIELD QUALITY CONTROL

A. Resident Engineer will inspect bolted connections for conformance to these Specifications including location, damage, and the manufacturer’s installation manual.

B. Replace bolted connections rejected by Resident Engineer for poor quality as not meeting manufacturer’s installation manual and replace with a new bolted connection at Contractor’s expense.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Description of power distribution systems for the 3 potential types of signal enclosures.

2. Design, procurement, installation, and testing requirements for Uninterruptible Power Supplies (UPS) and frequency converters.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. American National Standards Institute (ANSI)
   a. ANSI C62.41.1 - Guide on the Surge Environment in Low-Voltages (1000V and less) AC Power Circuits
   b. ANSI Z358.1 - Emergency Eyewash and Shower Equipment

2. Federal Communications Commission (FCC)

3. International Code Council (ICC)
   a. IBC - International Building Code

4. National Fire Protection Association (NFPA)
   a. NFPA 70 - National Electrical Code (NEC)
   b. NFPA 2001 – Standard on Clean Agent Fire Extinguishing Systems

5. National Electrical Manufacturer’s Association (NEMA)
   a. NEMA PB-1 - Panelboards
   b. NEMA PE-1 - Uninterruptible Power Systems (UPS)—Specification and Performance Verification


7. Underwriter’s Laboratories (UL)
   a. UL 1449 – Surge Protection Devices
   b. UL 1778 - Uninterruptible Power Systems
8. Washington Industrial Health and Safety Act (WISHA)

### 1.03 SUBMITTALS

A. Submit:

1. Product Data:
   a. Description and catalog cuts of proposed UPS, batteries, and frequency converters to be furnished including proven equipment history.
   b. Description and catalog cuts for AC power distribution material including, but not limited to, disconnects, panelboards, surge protection, breakers, fuses, and wiring for Sound Transit.

2. Certificates:
   a. Certified Factory Test reports for UPS and frequency converters.

3. Design Submittals:
   a. Power Calculations:
      1) Submit with power system plans for each location.
      2) AC and DC power calculations based on total peak and nominal load that will exist at each signal equipment location.
      3) Nominal load is defined as load for normal operation at 4-minute headway.
      4) Calculations shall derive load by showing power consumption of each type of device in the room. Where signal housing has separate panels for non-battery backed loads and panel for battery backed loads calculations shall show loads independently and shall identify loads for each 120 volt leg.
      5) Identify a nominal load for each UPS based on normal direction operations with 4-minute headway each direction.
      6) Voltage drop calculations for 240 Vac single-phase power connection to source and AC power distribution wiring within signal room in accordance with criteria specified in Section 34 42 08, External Signal Cable.
      7) Calculations for switch heater system and all system logic necessary to ensure that the total load of the signal house, switch heater and all other loads, does not exceed the allowable load for each location as shown in the Contract documents.
   b. UPS Calculations:
      1) Calculations showing UPS electrical size can meet peak load.
      2) Calculations showing UPS battery capacity.
   c. Power System Plans:
      1) Submit power system plans for each signal room.
2) Submit power system plans prior to obtaining Electrical Permits.

3) Provide single line drawings showing energy distribution to signal equipment.

4) Provide ratings of protective devices and transformers, including required cable and wire sizes.

5) Show layout of power equipment within signal room and signal house. Comply with NEC and all local code requirements, as interpreted by the Authority having jurisdiction.

1.04 QUALITY ASSURANCE

A. Provide power distribution materials and equipment furnished and installed to meet latest edition of National Electrical Code (NEC) and applicable state and local ordinances.

B. Calculations shall be checked, stamped, and signed by a Washington State licensed Professional Engineer.

PART 2 - PRODUCTS

2.01 ST SIGNAL HOUSE TYPES

A. ST utilizes 3 types of signal equipment houses (factory assembled mainline signal bungalows, civil contractor furnished station rooms, and factory assembled grade crossing control bungalows) as applicable to the location and each has unique power distribution requirements. Additional power system details are contained in Sections 34 42 38 – Wayside Enclosures and 34 42 22 Highway Crossings.

1. Factory Assembled mainline signal bungalows (bungalows containing Track Circuits): The power feed is to a house load panel that directly feeds non-battery backed up loads and provides a feed to a UPS backed up load panel. There shall be a transfer switch allowing plug connected emergency generator backup to the UPS. All equipment necessary to maintain normal signal control operation in event of a power loss shall be fed from the UPS panel. Where required, the mainline house shall also provide feeds (backup power not required) to switch heater enclosures and grade crossing housings.

2. Civil contractor furnished station rooms: These signal rooms have a single UPS fed panel that feeds all signal equipment. Lights, outlets, and other non-signal loads are part of the station power distribution system. There is no emergency generator backup connection for these rooms.

3. Factory assembled grade crossing control bungalows:
   a. These housings are to be equipped with one power panel for all loads.
   b. They are not to have a UPS or emergency generator connection.
   c. Signal equipment is backed up by Ni-CAD batteries.
   d. See Section 34 42 22 – Highway Crossings for more details.

2.02 INCOMING POWER

A. See the Contract Drawings for the location voltage level of the power drop for each signal location. This will very base on type of signal location:
1. Mainline, and Highway Crossing House locations will be provided with either:
   a. Power pedestal.
   b. Breaker in an adjacent ST facility.

2. Signal Rooms in ST facilities:
   a. A wall mounted disconnect.
   b. Breaker in a power panel in the signal room.

B. Provide all conduit and cabling from power drop to signal location.

C. Provide power distribution as shown on the standard drawing for each type of signal location.

D. Provide a step-down transformer at where required to reduce the power drop to the appropriate voltage level, in accordance with Section 26 05 17, Dry-Type transformers.

E. Provide an isolation transformer for all signal equipment, in accordance with Section 26 05 17, Dry-Type transformers.

F. Owner-furnished existing power products/systems:
   1. Sound Transit (via civil contract requirements or the design of a prime design-build contractor) will provide a power connection point designated for each signal house location. For crossing housings this may be to sub-feed it from the nearest mainline signal house. The Signal Contract Drawings designate the power connection point location and the power and voltage being furnished. The Contractor shall connect transform the voltage if necessary and distribute the power to his signal equipment.

   2. For signal rooms that are part of stations, Sound Transit (via a civil contractor or the design of a prime design build contractor) will provide power in signal room via a disconnect switch mounted on wall as shown on Contract Drawings.

   3. Provide transformer and design signal equipment AC power to be fed from secondary of an isolation transformer, in accordance with Section 26 05 17, Dry-Type Transformers, and at locations shown on the Contract Drawings.

2.03 SIGNAL POWER DISTRIBUTION EQUIPMENT
   A. Panelboards and Circuit Breakers: In accordance with Section 26 24 12, Panelboards and Circuit Breakers.

   B. Transformers: In accordance with Section 26 05 17, Dry-Type Transformers.

   C. Surge Suppression: Type 1, in accordance with UL 1449.

2.04 UNINTERRUPTIBLE POWER SUPPLY
   A. Manufacturer: Eaton Powerware 9155, or approved equal.

   B. Design UPS output to handle signal room peak load. Provide a minimum of 10 percent spare capacity for future expansion.

   C. Provide UPS equipment from only one manufacturer.
D. Design UPS to power equipment including, but not limited to, signal processors, track circuits, cab signals, TWCs, switch machines, and wayside signals.

E. Standards and Codes: In accordance with UL 1778, ANSI C62.41.1, FCC part 15, Class A, NEMA PE-1, and NFPA-70.

F. Able to operate in environment of signal room. The product shall have demonstrated 5 years of successful installation on a North American railroad or transit.

G. Environmental Range: 30 to 113 degrees F; relative humidity of 5 to 95 percent.

H. Output Regulation: Within plus or minus 2 percent over full range of battery voltage.

I. Voltage Output: Sinusoid 60 Hz output within plus or minus 0.5 percent with maximum 5 percent harmonic distortion over full range of input and battery voltage.

J. Input Voltage Range: Plus 10 percent to minus 15 percent.

K. Lagging Power Factor: 0.8 at full load.

L. Provide UPS capable of hot swapping of batteries.

M. Batteries:
   1. Nickel-Cadmium or Valve Regulated Lead Acid (VRLA).
   2. Battery Capacity: Sustain nominal UPS load plus 25 percent (for future expansion) for a period of 90 minutes.
   3. Mount batteries in a complete UPS cabinet designed to house UPS and batteries, or in additional external battery cabinets as necessary.
   4. Design UPS and battery cabinets, including ventilation requirements, to meet requirements of the authority having jurisdiction.

N. Submit certification that UPS equipment and installation is designed to withstand seismic forces in accordance with International Building Code, Seismic Zone 3 requirements.

O. By-pass switch:
   1. Type: Mechanical or solid state.
   4. Design switch to isolate UPS rectifier from inverter components.
   5. Design switch to automatically failover to room AC power source in the event of UPS output failure.
   6. Ensure AC power source is available even if there has been a short within UPS.

P. Alarms and Indications:
   1. Design of UPS shall include meters to indicate, at a minimum, output voltage and inverter current.
   2. Design of UPS shall include Ethernet connection to Signal Maintenance Computer and via a network to a remote location for display of diagnostic information.
3. **Alarms:**
   a. **UPS on Battery Alarm:** Indicates rectifier current is zero and load is being drawn solely from battery.
   b. **Bypass Indication:** Indicates UPS on bypass.
   c. **Summary Trouble Indication:** Indicates when trouble alarm is present on UPS.

2.05 **FREQUENCY CONVERTER**

A. **Input Voltage:** 120 Vac, 60 Hz service (from UPS panel via a dedicated breaker).

B. **Output Power:** Single-phase, two wire, isolated output adjustable from 105 to 130 Vac at 100 Hz.

C. **Size to continuously furnish a minimum of 125 percent field tested load.**

D. **Type:** Solid state, AC power source, synthesized sine wave.

E. **Load Power Factor:** 0.8 lead or 0.7 lag at rated output.

F. **Efficiency:** 70 percent minimum.

G. **Voltage Regulation:** Plus or minus 1 percent with line fluctuations of plus or minus 10 percent from no load to full load.

H. **Frequency Stability:** 2 percent maximum.

I. **Harmonic Distortion:** 4 percent maximum at loads or inputs specified herein.

J. **Meters, Panel:** Voltmeter, ammeter, and frequency meter with 2 percent minimum accuracy.

K. **Protection:** Provide input and output circuit protection as indicated on Contract Drawings.

L. **Frequency shall be stable in stand-alone operation.**

M. **Design converter with capability of being kept in phase via a phase lock circuit to an external synchronization signal if future operation requires synchronization to an adjacent location.**

N. **Alarms:**
   1. **Alarm Circuit Output:** Via discrete contacts.
   2. **Connect alarm contacts to non-vital processor for indication to TCS and local control panel, as part of a summary power supply alarm.**
   3. **Alarm Indications:** Report as part of a summary power equipment failure alarm.
   4. **Alarm Indications Include:**
      a. Overvoltage/undervoltage on output.
      b. Phase relation to sync greater than 10 degrees.
      c. Loss of synchronization signal.
2.06 CONTRACTOR SUPPLIED GROUNDING

A. Driven ground rods: 5/8" x 8'.

B. Conductor for ground ring; 4/0 AWG bare stranded copper.

C. Conductor for connection to corner of signal house: 2 AWG UV resistant green insulated stranded copper.

D. Conductor for mainline signal house test ground connection to rod independent of ground ring use 2 AWG UV resistant green insulated stranded copper.

E. Conductor for connection to service panel and ground fault detector test ground: 2 AWG bare stranded copper.

F. At tunnel signal rooms and other designated locations use the supplied grounding system to ground the signal equipment. Unless the Contract Documents specifically identify the grounding connection is furnished by ST, the Contractor shall be responsible for providing the grounding.

2.07 PORTABLE EYEWASH STATION

A. Portable Eyewash Station: In accordance with Section 22 45 19, Self-Contained Eyewash Equipment.

B. Standards and Codes: Conform to ANSI Z358.1 and WISHA.
   1. Design eyewash station to mount near any UPS or batteries. Product selection and mounting shall be chosen for minimal interference with passage or maintenance activities.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General:
   1. Provide a signal power distribution system compatible with signal system.
   2. Provide an UPS in all mainline signal houses or rooms that contain track circuits.
   3. Provide a 100 Hz frequency converter as source for power frequency track circuits.
   4. Provide power conditioning including, but not limited to, surge and noise suppression required on power feeds for rack mounted power supplies and located on power distribution racks.
   5. Install in compliance with NFPA 70, Seattle Mechanical Code, Seismic Zone 3 requirements, and Building Code of Authority Having Jurisdiction.
   6. Install equipment plumb and level.
   7. Mount power equipment on racks when available and alternatively on signal room walls.
   8. Provide unobstructed space around equipment for easy maintenance to greatest extent possible.
9. Mount power equipment not on racks using galvanized or stainless steel hardware and screws.

B. AC Power Distribution:

1. Incoming AC Components:
   a. Extend conduit from power source disconnect switch to isolation transformer.
   b. Provide a main panel board to protect complete room load at each signal room powered by UPS.
   c. Provide surge protection for power entrance to room.

2. Separate AC wiring from signal data wiring as much as feasible to avoid potential EMI issues.

3. Provide protection of terminals carrying 50 Vac, or above, from casual contact during maintenance or operation.

4. Provide protection on AAR terminal block posts carrying 120 V used on entrance rack, or as distribution points in equipment racks.

C. Electrical Identification: Provide nameplates on panelboards, transformers, and electrical wiring in accordance with Section 26 05 03, Electrical Identification and 34 42 55 – Internal Signal Cable.

D. Contractor Supplied Grounding:

1. Ground to earth resistance: 25 ohms or less.

2. Connect at least 3 corners of all signal houses to grounding system.

3. Connect service panel and ground fault detector test ground with separate conductors.

E. Portable Eyewash Station:

1. Commission eyewash in accordance with governing regulations and manufacturer requirements.

2. Maintain eyewash in accordance with manufacturer's guidelines until Final Acceptance.

3. Reference Section 22 45 19, Self-Contained Eyewash Equipment, for other installation requirements.

3.02 SIGNAL ROOM AS PART OF STATION ENCLOSURE INTEGRITY

A. ST will provide a clean agent fire suppression system in signal rooms furnished in ST facilities. The furnished room will conform to NFPA 2001 requirements for enclosure integrity.

B. Modifications to signal room including installation of power distribution equipment, internal cable in conduit, external cable through conduit to the entrance rack, and all other construction activities shall preserve room seal in accordance with NFPA 2001 Annex C – Enclosure Integrity Procedure. All conduits shall be sealed after cable installation and testing.
END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:

1. Furnishing and installing factory wired instrument houses and cases as described herein and as shown in the Contract Drawings.

1.02 REFERENCES
A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association Communications & Signal Manual of Recommended Practices (AREMA)


3. National Fire Protection Association (NFPA)
   a. NFPA 70 - National Electric Code (NEC)


5. Washington State Building Code

6. Underwriter’s Laboratories (UL)
   a. UL 38 – Standard for Manual Signaling Boxes for Fire Alarm Systems
   b. UL 521 – Standard for Heat Detectors for Fire Protective Signaling Systems
   c. UL 1008 - Transfer Switch Equipment

1.03 SUBMITTALS
A. Submit:

1. Product Data:
   a. A listing of each instrument house to be used on the job, along with its location and proposed size shall be submitted to Sound Transit within 90 days of Notice to Proceed (NTP).
b. Description and/or catalog cut of the proposed instrument houses including the proven equipment history.

c. Provide information of materials used to create the structure including electrical components, lighting, cable trays, insulation, and flooring.

2. Shop Drawings:

a. Drawings showing the proposed size, rack layout, and wall mounted equipment and the method of mounting the HVAC, emergency generator connection, local control panel, Signal Vital Processor (SVP), event recorders, communication interface equipment, plan rack and table, and construction of each instrument house.

b. Drawings showing the concrete foundations to be used and the ground grid to be installed.

c. Drawings of the pre-cast foundations the Contractor proposes to furnish and install. These drawings shall include, but not be limited to:

   1) Physical dimensions.
   2) Bolt spacing.
   3) Reinforcing steel.
   4) Size and detail of galvanized bolts, nuts, and washers.

d. Calculations for the type and quantity of foundations to be used for each installation. These calculations shall include, but not be limited to:

   1) Seismic loading.
   2) Wind loading.
   3) Signed and sealed by a Certified Washington State Structural Engineer.

3. Design of the fire detection system, intrusion detection system, and the environmental control system including cut sheets and plans.

B. Certificates: Labor and Industries Approval.

1. The submittals shall be separate and prior to the structural portion of the L&I gold seal permit application for each location the Contractor makes directly to L&I. Sound Transit will review the submittal for specification conformance prior to the permit applications.

2. Provide the Sound Transit copies of the electrical L&I gold seal permit applications the Contractor makes directly to L&I. Sound Transit will not review this package for approval. Sound Transit shall instead review for approval the electrical design submitted in Section 34 42 35, Signal Power Distribution System.

3. Test Requirements: Factory test procedure.
4. Special Procedures: Prepare building permit submittals for placing each housing on foundation. Provide the Resident Engineer copies of these permit applications. Sound Transit will not review these documents for approval.

C. Field Electrical Permits, Inspections, and Certification:
   1. Submit a copy of all electrical permits prior to installation of signal equipment and signal houses.
   2. After the signal house is installed on the foundation and connected to power, coordinate with the Authority Having Jurisdiction to schedule an electrical inspection, notify Sound Transit 24 hours prior to inspection.
   3. Repeat this for each signal house location. Incorporate any changes required to meet applicable codes at no additional expense to Sound Transit.
   4. Notify Sound Transit when field equipment is ready for the Sound Transit Self Certification Inspection.

PART 2 - PRODUCTS

2.01 ASSEMBLIES/EQUIPMENT/COMPONENTS/GENERAL REQUIREMENTS
   A. Construction: modular, minimum 0.100 inch aluminum or powder coated steel, dust tight, insulated. Line the top and sides of the houses with a fire resistant insulating material complying with the flame spread of 0-20 and a fire rating of seven in accordance with ASTM E84.
   
   B. Provide approved $\frac{3}{8}$ inch high tensile strength, silicon-manganese bronze stud bolts as shown on the Contractor’s approved house layout submittal drawings, for externally grounding the housing and providing independent test ground for ground detection system.

   C. Doors:
      1. Hinges: two minimum, separate castings, bronze or stainless steel hinge pins, pressure lubricating fittings, securely fastened to the housing and door. Lubricate hinges before the house is shipped.
      2. Retaining device: two position to secure the door open at 90 and 180 degrees. Prevent wear due to vibration when the door is closed and locked. Securely fasten a $\frac{3}{4}$ inch by two inch angle plate on the exterior of all instrument house doors with provisions made for a vandal proof lock to secure the door angle plate to an angle plate securely fastened on the instrument house. Provide this locking arrangement in addition to the normal locking mechanism and handle.
      3. Mainline bungalows shall have two individual exit doors plus doors that access the entrance rack terminals.

2.02 INSTRUMENT HOUSES
   A. Size: maximum 14 feet in width by 32 feet in length, houses less than 32 feet long shall be maximum 10 feet wide, 7 feet minimum interior headroom. Large enough to facilitate efficient maintenance, accommodate equipment required to implement the Contractor’s design. See Contract Drawings for house layout requirements. If Contract Drawings indicate a size for a location, it shall be considered a maximum size unless special permission is obtained from the RE.
B. Spare capacity:
   1. Mainline signal houses minimum 2 rack spaces.
   2. Signal houses at terminals shall have 4 spare rack spaces.

C. Insulation value, entrance doors, and walkways:
   1. Construct house to meet the requirements of the latest versions of Chapter 50-51 WAC as required by WA L&I and the local authority having jurisdiction.

D. Electrical Working Clearance:
   1. Install all energized electrical power equipment with working clearance per the NEC as enforced by the local authority having jurisdiction.

E. Design doors to provide a dust proof and weatherproof seal.

F. Cover the entire floor with 1/2" rigid insulation and 3/4" fiberglass reinforced polyurethane composite fiberboard with anti-skid textured finish and rated at 24,000 volts AC dielectric strength.

G. Provide fluorescent lighting above the aisles to provide illumination to both sides of the equipment racks, wall shelves, and the plan table area.

H. Environmental Controls:
   1. Provide environmental controls including air conditioning unit and ventilation to maintain a temperature between 60 and 78 degrees F under normal operating condition heat loads as defined by four minute operating headways and a personnel load of at least four. Assume maximum exterior temperature to be 98 degrees F.
   2. Air changes: minimum of 20 air changes per hour.
   3. Air filtration: MERV 9 filters minimum.
   4. Ensure air conditioner drains to the exterior of the house. Interlock thermostat controls such that heating and air conditioning cannot both be on.
   5. Ensure all HVAC and other ventilation equipment meets the acoustic requirements of all applicable building codes and does not create and ambient noise level higher than 72 dBA in any public area.

I. Fire Detection System:
   1. Thermal fire detector: Provide two thermal fire detectors with fixed temperature and rate-of-rise capabilities in accordance with UL 521.
   2. Ionization Detector:
      a. Provide two ionization detectors activated by products of combustion.
      b. Sensitivity: Adjustable with minimum level required by UL, unaffected by rapid changes of humidity.
      c. Type: UL listed, multiple use, plug-in units containing two chambers with no moving parts, and contain no material requiring licensing by the Atomic Energy Commission for this application.
d. Detector base: Screw terminals, neon indicator, standard base to accommodate a thermal rate-of-rise detector without additional wiring.


4. Send a fire alarm to Link Control Center (LCC) fire alarm network (part of Building Management System).

J. Intrusion Detection: Detect opening of a door, sound an audible warning and send alarm to Building Management System. Provide keypad near front door to disable alarm an adjustable time prior to alarm sounding. Intrusion detection system shall be fed by a separate breaker and have enclosed battery backup.

K. Combined fire/intrusion detector with keypad, horn battery box, four wire ionization detector and thermal detector may be used.

L. Incoming Ac Components:
   1. Extend conduit stub-up to the main panel board (or possible transformer before connection to the main panel board).
   2. Main panel board: main disconnect 240 Vac circuit breaker, protects complete house load.
   3. Vital panel board: Protects the signal loads powered by the UPS.
   4. Provide surge protection for the power entrance to the house.

M. Automatic Transfer Switch:
   1. Switch between normal utility source and standby generator external to house.
   2. Size transfer switch for the bungalow load as required by the NEC.
   4. Power input: 240/120 single-phase from main panel load. For 480 volt input locations, transfer switch shall be between the transformer 240 volt secondary and the main breaker panel.
   5. Close-on rating: 10,000 amps when protected by current breakers.
   7. Type: Double-throw, inherently interlocked construction to absolutely prohibit connection of the two sources.
   8. Standards: In accordance with UL 1008 and NEC.

N. Generator connection:
   1. Compatible with existing signal houses.
   2. Mounting: Integral to the wall of instrument house.
   3. Ratings:
      a. 100 amp.
      b. 600 Vac/ 250 Vdc.
c. 50 – 400 Hz.

4. Description and Configuration:
   a. Metallic – Cast Aluminum.
   b. 3 Wire.
   c. 4 pole.
   d. Type 2, NEMA 4, spring loaded or screw type cap, keyed to prevent miss-polarization.

5. Manufacturer: Crouse Hines Arktite, or approved equal.

6. Ground conductor: Connect to instrument house main ground.

O. Panelboards and Circuit Breakers: In accordance with Section 26 24 12, Panelboards and Circuit Breakers.

P. Provide and external light near entrance door and external power panel opening at above door height.

Q. Transformers: In accordance with Section 26 05 17, Dry-Type Transformers.

R. Grounding Bus: Nickel plated hard drawn pure copper grounding bus, with a minimum dimension of eight inches by eight inches by 1/2 inch thick. Drill and tap a minimum of twelve 3/8 inch holes and install twelve 3/8 inch by 1/2 inch long hex head nickel plated bronze studs with one washer.

S. Internal Ground Wire: Insulated No. 6 AWG stranded internal ground wire with green insulation.

T. Ground Rods: Copper-clad steel ground rods of the non-rusting type, as manufactured by the Copperweld Corporation, or approved equal, at least eight feet in length and at least 5/8 inch in diameter. Exothermically weld ground rod connection to ground rod, Cadweld type GR or GT, or approved equal. All work to be performed in accordance with Section 26 05 26, Grounding and Bonding.

2.03 GRADE AND SPECIAL CROSSING HOUSES

A. Size: maximum 6 feet in width by 6 to 12 feet in length. Large enough to facilitate efficient maintenance, accommodate equipment required to implement the Contractor’s design.

B. Spare capacity: minimum 25 percent more equipment and main terminal board space than initial design.

C. Insulation value, entrance doors, and walkways:
   1. Construct house to meet the requirements of the latest versions of Chapter 50-51 WAC as required by WA L&I and the local authority having jurisdiction.

D. Electrical Working Clearance:
   1. Install all energized electrical components with working clearance per the NEC as enforced by the local authority having jurisdiction.

E. Design doors to provide a dust proof and weatherproof seal.

F. Cover the entire floor with fiberglass reinforced polyurethane composite fiberboard with anti-skid textured finish and rated at 24,000 volts AC dielectric strength.
G. Provide fluorescent lighting above to provide illumination of the equipment.

H. Environmental Controls:
   1. Provide ventilation to maintain the interior temperature below the maximum operating temperature of all the installed equipment, under normal operating conditions. Assume maximum exterior temperature to be 98 degrees F.
   2. Air filtration: MERV 9 filters minimum.

I. Fire Detection System:
   1. Thermal fire detector: Provide two thermal fire detectors with fixed temperature and rate-of-rise capabilities in accordance with UL 521.
   2. Ionization Detector:
      a. Provide two ionization detectors activated by products of combustion.
      b. Sensitivity: Adjustable with minimum level required by UL, unaffected by rapid changes of humidity.
      c. Type: UL listed, multiple use, plug-in units containing two chambers with no moving parts, and contain no material requiring licensing by the Atomic Energy Commission for this application.
      d. Detector base: screw terminals, neon indicator, standard base to accommodate a thermal rate-of-rise detector without additional wiring.
   3. Manual pull station: single action, in accordance with UL 38, convenient and easily accessible, activates audible and visual indicating devices.
   4. Send a fire alarm to Link Control Center (LCC) and to report on the Emergency Ventilation System.

J. Intrusion Detection: detect opening of a door, sound an audible warning and send alarm to Building Management System. Provide keypad near front door to disable alarm an adjustable time prior to alarm sounding. Intrusion detection system shall be fed by a separate breaker and have enclosed battery backup.

K. Combined fire/intrusion detector with keypad, horn battery box, four wire ionization detector and thermal detector may be used.

L. Incoming Ac Components:
   1. Extend conduit stub-up to the panel board.
   2. Main panel board: Main disconnect 240 Vac circuit breaker, protects complete house load.
   3. Provide surge protection for the power entrance to the house.

M. Ground conductor: Connect to instrument house ground.

N. Panelboard and Circuit Breakers: In accordance with specification Section 26 24 12, Panelboards and Circuit Breakers.

O. Transformers: In accordance with specification Section 26 05 17, Dry-Type Transformers.

P. Grounding Bus: Nickel plated hard drawn pure copper grounding bus, with a minimum dimension of eight inches by eight inches by 1/2 inch thick. Drill and tap a minimum of
twelve 3/8 inch holes and install twelve 3/8 inch by 1/2 inch long hex head nickel plated bronze studs with one washer.

Q. Internal Ground Wire: Insulated No. 6 AWG stranded internal ground wire with green insulation.

R. Ground Rods: Copper-clad steel ground rods of the non-rusting type, as manufactured by the Copperweld Corporation, or approved equal, at least eight feet in length and at least 5/8 inch in diameter. Exothermically weld ground rod connection to ground rod, Cadweld type GR or GT, or approved equal.

2.04 WAYSIDE CASES

A. Door Handle: Make provisions for locking with a standard padlock. The handle shall utilize a multi-point locking system.

B. Provide front and back door cabinet unless Contractor can demonstrate that all wire connections, all tags can be read, and indicators or test points can be maintained from the front. If no rear door is proposed, the Contractor shall also demonstrate that wiring modifications can be made from the front without dismounting equipment or disturbing wiring harnesses.

C. Door vents: Minimum of two per door, covered with fine mesh stainless steel, copper, or bronze screening. Hood the exterior to minimize the entrance of rain. Doors shall be gasketed.

D. Provide vent fan with control by an adjustable temperature thermostat.

E. Provide one duplex convenience outlet (min).

F. Provide a switched medium base lamp holder with a 120 volt, 60 watt equivalent LED lamp at each door.

G. Equipment Racks: Manufactured to fit the type of equipment furnished and the wayside case, include necessary supports for wire and equipment, provide minimum 20 percent spare capacity.

H. Terminations: see section 34 42 55, Internal Signal Cable.

I. Paint case interior white and in accordance with the manufacturer’s recommendations.

J. Unless the case is specifically required to be fiberglass in the Documents, the case shall be made of either 12.5 inch aluminum alloy type 5052-H32, 14 gauge minimum 304 stainless steel, or steel powder coat covered to colors selected by ST.

2.05 PRECAST FOUNDATIONS

A. Precast Concrete Foundations:

1. All foundations shall be furnished and installed in accordance with the bungalow manufacturer’s recommendations, and shall be complete with galvanized bolts, washers, nuts, and associated hardware. Galvanizing shall conform AREMA 15.3.1.C – Galvanized Hot-Dipped Coating Criteria.

PART 3 EXECUTION

3.01 INSTALLATION

A. Instrument Houses:
1. Install the instrument house in location shown on the Contract Drawings. Mount each instrument house on pier foundations, existing pavement, or pad foundation as shown on Contract Drawings. Level and plumb each instrument house. Use foundations, hardware, and number of piers as necessary to meet seismic zone 3 requirements.

2. House Layout:
   a. House layout shall take into account lighting, troubleshooting ease, human factors, and shall be approved by Resident Engineer before commencing installation.
   b. Provide instrument racks, equipment, and necessary mounting and fastening materials. House shall be designed to install instrument racks electrically isolated from each other and the house except through the rack ground wire.
   c. Provide a separate 19 inch rack to mount communications equipment. Equip rack with power and ground.
   d. Furnish space for a wall mounted telephone near the local control computer.
   e. Provide a desk chair for the operator’s use while operating the SMC. Provide plan space in a shelf or with a plan rack near to the desk.

3. Grounding:
   a. Provide a ground grid using at least four ground rods. The ground rods shall be connected together by a 4/0 bare copper wire. Connections to the 4/0 copper wire shall be by thermite welding.
   b. Provide a ground bus of pure hard drawn copper plate, eight inches square (minimum) and ½ inch thick, at the bottom of the entrance rack. Connect the ground bus to the ground grid with a minimum of two #2 AWG copper conductors.

B. Wayside Cases:

1. Wayside cases installed at-grade shall have precast foundations or concrete pad as shown on the Contract Drawings

2. Mount wayside case level and plumb. Wayside cases with trackside doors in the open position shall clear center line of the nearest running track by eight feet, six inches, unless otherwise approved by Sound Transit. In areas with restricted clearance, the trackside doors shall clear center line of track by minimum of seven feet.

3. Install pipes for underground cable entrances in the knockout holes provided in the bottom of each case. Secure the pipes to each case by locknuts and bushings. Cables shall enter wayside cases by entrance knockouts provided. Fasten wiring raceway by an approved fastening method. Seal cable entrance pipes with a sealing compound as specified in Section 34 42 97, Miscellaneous Hardware.

4. Connect the grounding pigtail to the 3/8 inch stud bolt provided with each case.
5. Inspect the paint of each wayside case after installation and repair any damage in accordance with the paint manufacturer’s instructions and as approved by Sound Transit.

C. Precast Foundation:

1. Size and quantity of foundations shall be accordance with the seismic calculations for the size, weight, and location of each house or case.

2. Install in accordance with the bungalow manufacturer’s recommendations.

END OF SECTION
SECTION 34 42 53
INSTRUMENT RACKS

PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
   1. Design, procurement, and installation of instrument racks and Main Terminal Board (MTB).

1.02 REFERENCES
A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:
   1. American Railway Engineering and Maintenance-of-Way Association Communications & Signal Manual of Recommended Practices AREMA
      a. Part 14 - Electrical Devices, Foundations, and Hardware
   2. International Code Council (ICC)
      a. IBC - International Building Code

1.03 SUBMITTALS
A. Submit:
   1. Shop Drawings:
      a. Detailed arrangement plans of equipment on each rack prior to assembly of racks.
      b. Room layout installation drawings showing equipment locations.
      c. Drawings showing method of grounding.
      d. Drawings showing proposed method of mounting signal maintenance computer, vital microprocessor, event recorders, communication interface equipment, and plan rack and table.
   2. Design Submittals: Calculations showing rack installation meets local and state seismic codes. Calculations shall be performed and sealed by a structural engineer registered in Washington.
   3. Powder coat or paint material and procedure.
   4. Special Procedures:
      a. Rack Name Tag Information Including: Type, appearance, size, and mounting method.
1.04 DELIVERY, STORAGE AND HANDLING.

A. Delivery and Acceptance Requirements: Ship racks for signal rooms in individual crates, racks in pre-fab signal house are to be shipped installed in the house but shall be secured so that they are not damaged during shipping. Inspect all racks upon arrival for any damage in shipping.

B. Storage and Handling Requirements: Store racks for the signal rooms in their shipping crates, inside a building prior to installation, only remove them from the crates after they have been transported to the station signal room.

PART 2 - PRODUCTS

2.01 INSTRUMENT RACKS

A. Frame: 14 gauge minimum cold rolled steel, open frame weldments to accommodate mounting of standard 19-inch panels, fire-retardant.

B. Height: 7 feet 6 inch maximum.

C. Grounding Posts and Grounding Jumpers: Bolted type to permit isolation of rack for testing by removal of ground wire connections.

D. Internal Ground Wire: No. 6 AWG stranded ground wire, green insulation.

E. Chassis Supports: 11 gauge minimum cold rolled steel, capable of being mounted directly to panel-mounting plugboard support bars for each row of relays and be of sufficient strength to support manufacturer’s equipment to be mounted thereon.


G. Finish: Powder coat or paint.

H. Wire Supports: Steel or material of non-flammable composition.

2.02 MAIN TERMINAL BOARD

A. Construction:
   1. Width: Maximum 12 inches from wall.
   2. Frame: 14 gauge minimum, cold rolled steel.
   3. Material: Fire resistant or fire retardant plywood.
   4. Paint: One coat universal alkyd primer and one finish coat of latex paint matching the manufacturer’s standard for entrance racks.

B. Internal Ground Wire: No. 6 AWG stranded ground wire, green insulation.

C. Grounding Plates: 1/2-inch thick minimum, copper with nickel plating, corners free of sharp edges.

D. Fully equip main terminal boards with required number of terminal blocks, tags, rack and row identification, and accessories.
E. Terminal Mounting:
   1. Arrange terminal blocks and spacing of terminals to permit each internal wire and its field wire interconnection to be separated on an individual basis, without removing either wire from its terminal.
   2. Provide test link straps.
   3. Spare Terminal Posts: 10 percent spare with a minimum of 25 for each rack.

F. Grounding Plates: Bolted type to permit removal of ground wire connection for testing.

2.03 FOLD-UP DESK
A. At pre-fabricated signal rooms only provide a plan desk.
B. Material: Steel, minimum 14 gauge.
C. Mounting: Wall mounted.

PART 3 - EXECUTION
3.01 HOUSE/ ROOM LAYOUT
A. Final house/ room layout is at discretion of Contractor, but shall be uniform over all rooms. Modifications to equipment provided by others as shown on Contract Drawings required by room layouts that deviate from Contract Drawings shall be at no cost to Sound Transit.
B. House/ room layout shall take into account lighting, troubleshooting ease, human factors, and shall be approved by Resident Engineer before commencing installation.
C. House/ room has been designed to install instrument rack sections as shown on approved installation drawings.
D. Provide instrument racks, equipment, and necessary mounting and fastening materials.
E. See Contract Drawings for equipment relative locations, clearance requirements, spare racks, and other requirements.

3.02 INSTRUMENT RACKS
A. When signal room is part of a station, parking garage or any other ST facility then paint signal room floor with electrically conductive epoxy to create a surface which is static dissipative before installing racks or equipment in signal rooms. Apply a minimal thickness of 50 mils, or greater if recommended by the manufacturer, to the entire floor of each signal room.
B. Locate terminal, plug connector, resistors for energy buses, and power panel on upper portion of rack for connecting wires and cables.
D. Provide a typed or printed name tag on a front plate of each rack or cabinet.
E. Provide wire supports for interior wire raceway.
F. Provide chassis supports or guides for auxiliary support of heavy equipment, such as power supplies.

G. Powder coat or paint each instrument rack.

H. Provide a minimum of 15 percent spare terminals on each instrument rack.

3.03 GROUNDING

A. Install instruments racks in such a manner as to be insulated from ground and from supporting frameworks or wire troughs.

B. Connect each grounding post or plate to main ground bus located on entrance rack with a #6 AWG green insulated conductor.

C. Provide grounding posts and ground jumpers with each rack.

D. Provide grounding plate(s) with each main terminal board section sized sufficiently for installed and spare cabling.

E. Electrically connect racks and main terminal board sections to each other only by internal ground cable.

3.04 RELAY AND COMPONENT MOUNTING

A. Group rows of racks and instruments so that similar types of equipment or functions of a similar nature are adjacent to each other.

B. Mount relays or components below 6 feet 6 inches from floor of the room.

C. Mount relays or components above 10 inches from floor of the room.

D. Provide a minimum of 20 percent spare space on each instrument rack for additional equipment.

E. Provide two spare cable plug connectors for each rack with plug connectors.

3.05 WIRING

A. Wire instrument racks in accordance with Section 34 42 55, Internal Signal Cable.

B. Pre-wire instrument racks, insofar as possible, at place of manufacture.

C. Use same interconnecting cables in field installation that were used in factory test of instrument racks.

D. Provide vital inter-rack wiring direct from relay to relay.

E. Harness field-installed wire bundles within rack in a neat manner and tied with nylon tie wraps.

F. Provide insulated terminal cap nuts to terminals with 120 or higher volts.

3.06 MAIN TERMINAL BOARD

A. Terminate incoming wires, including spare wires, on AREMA terminal binding posts in accordance with AREMA Signals and Communications Manual, Part 14.1.5.

B. Provide terminal board racks for terminating incoming wire and cable and making interconnections to internal wiring on instrument racks.
C. Install interconnecting cables, wiring, and connections and terminate incoming cables as shown on approved drawings.

D. Provide necessary fittings and fastenings materials.

E. Properly anchor to wall in accordance with seismic requirements.

F. Provide materials needed to assemble main terminal boards one to another to form complete sections.

G. Route wires from cable tray in Panduit or approved equal cable management system along board surface to terminal location.

H. Provide a terminal tag or cable tag for each terminal and terminating wire.

I. Provide gold nut connection for cables leaving the signal house.

3.07 SEISMIC DESIGN AND BRACING

A. Equipment provided under this Contract shall meet seismic requirements specified in IBC.

B. Support racks at top and bottom.

C. Provide suitable bracing and anchorage.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Design, procurement, installation, and testing of internal wire and cable.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. American National Standards Institute (ANSI)
   a. ANSI C1 - Specifications of General Requirements for a Quality Program

   a. Part 10 - Wire and Cable
   b. Part 14 - Electrical Devices, Foundations, and Hardware

3. ASTM International (ASTM)
   a. ASTM B3 - Specification for Soft or Annealed Copper Wire
   b. ASTM B33 - Specification for Tinned Soft or Annealed Copper Wire for Electrical Purposes
   c. ASTM B189 - Specification for Lead-Coated and Lead-Alloy-Coated Soft Copper Wire for Electrical Purposes
   d. ASTM D570 - Standard Test Method for Water Absorption of Plastics

4. Insulated Cable Engineers Association (ICEA)
   a. ICEA S-95-658/ NEMA WC 70 – Non-shielded Power Cables Rated 2000 Volt or Less

5. Military Specification (MIL)
   a. MIL-W-22759/ SAE AS22759 - Wire, PTFE, ETFE Insulated, Copper or Copper Alloy Conductor

6. Institute of Electrical & Electronic Engineers, Inc. (IEEE)
   a. IEEE 383 - Standard for Qualifying Class 1E Electric Cables and Field Splices for Nuclear Power Generating Stations
7. National Electrical Manufacturer’s Association
   a. NEMA HP 100 - High Temperature Instrumentation and Control Cables
   b. NEMA HP 100.2 - High Temperature Instrumentation and Control Cables Insulated and Jacketed with ETFE Fluoropolymers

8. SAE International (SAE)
   a. SAE AS22759/16 - Wire, Electrical, Fluoropolymer-Insulated, Extruded ETFE, Medium Weight, Tin-Coated Copper Conductor

9. Underwriter’s Laboratories (UL)
   a. UL 224 - Extruded Insulated Tubing
   b. UL 1581- Electrical Wires, Cables, and Flexible Cords

1.03 SUBMITTALS
   A. Submit:
      1. Product Data: Manufacturers’ product datasheets and complete technical data for the cable and ancillary devices proposed to furnish.
      2. Test and Evaluation Reports:
         a. Testing Documents Certified test reports for factory testing.
      3. Manufacturer’s Instructions:
         a. Cable Manufacturer Documents.
         b. Cable Installation Plans.
         c. Cable Pulling Report: In accordance with requirements of Section 26 05 19, Low-Voltage Conductors and Cables.

1.04 QUALITY ASSURANCE
   A. Cable Manufacturer Documents: In accordance with Section 34 42 08, External Signal Cable. Provide manufacturer with copy of N830 Section 34 42 55, Internal Signal Cable.
   B. Quality Assurance Program: In accordance with MIL-W-22759.
   C. Wires and cables shall meet or surpass tests and requirements specified in AREMA Communication and Signal Manual, Part 10.

1.05 DELIVERY, STORAGE AND HANDLING
   A. Delivery, Storage, and Handling: In accordance with the requirements of Section 34 42 08, External Signal Cable.

PART 2 - PRODUCTS

2.01 STRANDED WIRE
   A. Conductor: Stranded Soft Annealed Copper in accordance with ASTM B3.
B. Coating: Tin or lead in accordance with ASTM B33 or B189.

C. Construction: In accordance with Table I of SAE AS22759/16.

D. Abrasion Resistance: In accordance with Table A.

**TABLE A  
ABRASION RESISTANCE**

<table>
<thead>
<tr>
<th>Wire Size (AWG)</th>
<th>Min. Resistance (Inches of Tape)</th>
<th>Weight Support Bracket</th>
<th>Weight (Pounds)</th>
<th>Tension Load (Pounds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>22</td>
<td>26</td>
<td>A</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>20</td>
<td>26</td>
<td>A</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>18</td>
<td>27</td>
<td>A</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>16</td>
<td>28</td>
<td>A</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>14</td>
<td>19</td>
<td>B</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>12</td>
<td>29</td>
<td>B</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>10</td>
<td>36</td>
<td>B</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>B</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

E. Bend Testing: In accordance with Table II of SAE AS22759/16.

F. Insulation: Ethylene-Tetrafluoroethylene (ETFE) in accordance with NEMA HP 100 and NEMA HP 100.2.

G. Flame Spread Test: UL 1581.


2.02 MULTI-CONDUCTOR CABLE

A. Outer Jacket: Thermoplastic Rubber (TPR) rubber, in accordance with IEEE 383, stabilized for outdoor exposure.

B. Outer Sheath: Nominal thickness in accordance with ICEA S-95-658.

C. Barrier Tape: 0.005 inch thick; minimum 25 percent overlap.

D. Individual Conductors: Sized to meet 150 percent of load requirements, minimum 20 AWG, stranded.

E. Cables: Maximum 50 conductors, for use with non-vital plug connectors.

F. Multi-Conductor Cables: Minimum two spare conductors.

G. Assemble individual or twisted pairs, of insulated wires into a tight, cylindrical form. Assemble individual or twisted pairs helically and with adjacent layers wound in opposite directions.

H. Place finished cables in water at room temperature. After 48 hours immersion and while still immersed, test conductors for breakdown at a voltage of 2,500 V (rms) for five minutes.

2.03 IDENTIFICATION

A. Individual Conductors:

1. Marking Interval: Maximum 12 inches.
2. Identifying Markings: Permanent, easily readable and understandable.

3. Mark each individual conductor with the following information:
   a. Manufacturer’s name.
   b. Year in which wire is manufactured.
   c. Size of conductor.
   d. Type of insulation.

B. Multi-Conductor Cable:
   1. Stranded wires used in multi-conductor cable: Numbered or color coded in addition to the basic four-part identification.
   3. Mark cable outer sheath with the following information:
      a. Manufacturer’s name.
      b. Year of cable manufacture.
      c. Number and size of conductors.
      d. Type of insulation in wires.
      e. Type of outer sheath insulation.
      f. Voltage rating.

C. Wire Tags:
   1. Approved Manufacturers: Brady HEATEX™ labels or approved equal.
   4. Print: Wire origin, destination, and function.

D. Cable Tags:
   1. Approved Manufacturers: Brady HEATEX™ labels or approved equal.
   3. Attachment: Attach to cable with cable ties, both ends.
   4. Zero Halogen: In tunnel areas use zero halogen tags, that if burned, the waste products will only be H₂O and CO².
   5. Print: Cable origin, destination, and function.

2.04 TERMINALS

A. Terminate inter-rack vital and non-vital wiring including spare conductors on approved terminal blocks or with approved connectors.

C. Stranded wire, compression-type, insulated wire terminals: In accordance with AREMA Communications and Signal Manual Part 14.1.1 and Section 34 42 97, Miscellaneous Hardware.

D. Compression-type insulated terminal connections: single washer on top of terminal, require two washers for one terminal, three washers for two terminals, complete with double nuts torqued to rated value of nut.

E. DIN rail type terminals shall be spring compression terminals as manufactured by Wago, Enterlec, or Weidmuller.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Installation design and methods shall conform to:

1. Cable manufacturer's pulling requirements.
3. NEC
4. NECA 1

B. Provide internal wire and cable for connections between equipment in signal rooms.

C. If energy is distributed to various points in a signal equipment room or junction box by wire loops, show details of loops and its various connections on circuit plans. Connect both ends of wire loops to the bus.

D. Internal wiring design shall contain no point-to-point redundancy of wires for increased current capacity.

E. Tie wiring and cabling dress in harness arrangements with a high strength approved dielectric wire tie designed not to invade wire insulation. Use of electrical tape is not permitted for securing wiring and cables. Trim and locate ties to eliminate hazard to personnel from sharp edges.

F. Provide nylon straps for bundling and cabling of conductors where two or more single conductors are exposed in internal rack bundles, cable trays, or whenever wires are to be bundled. Install straps on cables at intervals of two feet minimum.

G. Cable Tray Installation:

1. Lay cables in place; do not pull cables. Provide a minimum amount of crossover between cables.
2. Equip cable trays with dividers to separate power, signal, and communications cable.

H. Terminations:

1. Observe minimum bend radius while training wires and cables into final position. Provide slack at terminals in an amount sufficient for two re-terminations.
2. Perform termination work under clean and dry conditions. Install wire terminals only with tools and techniques recommended by terminal manufacturer. Install no more than two wires on one AAR terminal binding post.

3. Terminate track wires and cables on lightning arresters. Terminate inter-rack vital and non-vital wiring including spare conductors on AAR terminal blocks.

4. Edge connector cables from Signal Vital Processor (SVP) printed circuit boards, electronic modules, and inter-rack wiring to/from SVP may be terminated on spring compression terminals located at top of SVP rack.

5. Plug connectors may be used for inter-rack wiring in accordance with Section 34 42 57, Plug Connectors.

I. Identification:

1. Tag wires and cables during termination process. Tag both ends of wires and terminal boards.

2. Each tag shall include three lines: Terminal location; circuit function nomenclature; terminal location on other end of wire.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Procurement and installation of plug connectors.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. Military Specification (MIL)
   a. MIL-STD-202 - Test Method Standard for Electronic and Electrical Component Parts

1.03 SUBMITTALS

A. Submit:

1. Product Data: Description and catalog cut of proposed plug connectors to be furnished including proven equipment history.

2. Shop Drawings: Complete drawings for each type of plug connector to be used prior to manufacture or procurement of plug connectors. Include complete parts lists and information required to order replacement parts

PART 2 - PRODUCTS

2.01 PLUG CONNECTORS

A. Block Assembly:

1. Material: Two part molded plastic connector block.

2. Connector Assemblies: Mechanically locked and keyed for both connector block halves, with tolerance that allows connector to be connected and disconnected easily by hand.


B. Pin-and-Socket Contacts:


2. Number: Maximum of 50.

3. Material: Commercial bronze or brass, plated with gold over nickel under plate.
5. Wire Sizes: Accept wire sizes 16 through 22, AWG.
6. Termination Resistance: In accordance with Method 307 of MIL-STD-202, at rated current specified for each wire size listed in Table A.
7. Spare Contacts: 20 percent spare.
8. Current Rating and Termination Resistance: In accordance with Table A.

<table>
<thead>
<tr>
<th>Wire Size (AWG)</th>
<th>16</th>
<th>18</th>
<th>20</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Current Rating (Amperes)</td>
<td>13</td>
<td>10</td>
<td>7.5</td>
<td>5</td>
</tr>
<tr>
<td>Maximum Termination Resistance (Milliohms)</td>
<td>1.7</td>
<td>2</td>
<td>2.7</td>
<td>4</td>
</tr>
</tbody>
</table>

PART 3 - EXECUTION

3.01 INSTALLATION/APPLICATION – PLUG CONNECTORS

A. Provide multiple position connector assemblies.
B. Provide a strain relief device for wiring after it leaves connector assembly.
C. Provide means to mechanically lock and key the connector assembly.
D. Provide 8 sets of tools used to apply plug connector contacts to wire and tools used to extract contacts from plug connector blocks of size and type recommended by manufacturer of plug connector assemblies. For each tool, furnish instructions for a complete plug connector assembly.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. Section includes:
   1. Design, procurement, installation, and testing of vital relays and non-vital relays.
B. Contractor shall use Signal Vital Processor (SVP) logic to minimize the need for relays.
C. Relay logic functions shall include:
   1. Signal lighting.
   2. Traffic, use mag stick relay.
   3. System transfer.
   5. Line wire drivers and receptors.
   6. AC Power Frequency Track Circuit.
   7. Non-vital alarms.

1.02 REFERENCES
A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.
   1. American Railway Engineering and Maintenance-of-Way Association Communications & Signal manual of Recommended Practices (AREMA)
      a. Part 2 - Railway Signal Systems
      b. Part 6 - Relays

1.03 SUBMITTALS
A. Submit:
   1. Product Data: Description and catalog cut of proposed relays be furnished including proven equipment history of 5 years successful service in North America.
   2. Upon final verification, index relay form cards by serial number and submit them.
   4. Calculations:
a. Calculations to determine timing characteristics (both slow pick and drop) for time element relays provided under this Contract.
b. Calculations for “software” timing relays used as a part of a microprocessor system.

5. Testing Documents:
   a. General: Submit relay testing documents under this Section.
   b. Source Quality Control:
      1) Test Program Plan for factory testing.
      2) Test Procedures and Test Results for each factory test for each vital relay, prior to shipment.
      3) Certified Test Reports for factory testing.
   c. Field Quality Control:
      1) Test Program Plan for field testing.
      2) Test Procedures and Test Results for each field test for each vital relay.
      3) Certified test reports for field testing


B. Closeout Submittals:
   1. Operation and Maintenance Data: manual describing operation and maintenance of each vital and non-vital relay used on the job.

1.04 DELIVERY, STORAGE AND HANDLING

A. Delivery, Storage and Handling Requirements:
   1. Ship vital relays separately from wired racks in which they are to be used.
   2. Package vital relays individually, each in a sturdy corrugated cardboard box with rack or mounting position of relay printed on box.
   3. Store relays in a protected area until tested and installed.

PART 2 - PRODUCTS

2.01 RELAYS

   A. Relays of Each Type: Uniform in design and contact assembly.
   B. Enclosures: Dust-proof, provisions for ventilation and heat dissipation.
   C. Material: Non-combustible.
D. Mounting: Rack mounted.

E. Nominal Voltage: 12 Vdc or Resident Engineer approved.

F. Operable Voltage Range: 7 Vdc to 21 Vdc.

G. Relays: Operable on nominal voltage, capable of picking up and continuous operation without damage when energized in operable voltage range.

H. Base: Plug-in, keyed to prevent wrong type, style, contact configuration, or operating characteristics from being installed into wrong plug base.

I. Relays shall comply with or exceed requirements of the following AREMA Communication and Signals Manual.
   1. Part 6.1.20, Recommended Design Criteria for Time-Element Relay, Tractive-Armature Type.
   5. Part 6.2.1, Recommended Design Criteria for Tractive-Armature Direct Current Neutral Relay, Plug-In Type.

2.02 VITAL RELAYS

A. Front Testing Arrangement: Permits energization and de-energization of relay without disturbing relay or wiring.

B. Arc Suppression: Built into relay or attached to base for vital coils.

C. Relay Bases: Equipped with removable receptacle springs.

D. Dc Relays: By same manufacturer.

E. General Purpose Relays:
   1. Six dependent front-back contacts.

F. Switch Operating Relays: Unless a vital solid state switch driver module is used in place of the following
   1. Switch operating relays shall be identical.
   2. Type: Biased neutral relay.
   3. Extra Heavy Duty Contacts: Minimum of four, magnetic blowout feature to effectively interrupt high currents and minimize wear.

G. Timer Relays:
2. Vital timer relays shall be identical.
3. Adjustment Increment: A minimum of 1.0 second or less.
4. When sealed, it shall not be possible to adjust timing intervals.
5. Use of resistors, capacitors, or diodes in parallel or in series with relay’s coil shall not be allowed as a means to adjust the time.

H. Vital Ac Track Relays:
1. Ac Track Relays: By same manufacturer.
2. Type: Two element 100 Hz vane.
3. Voltage Range Local Winding: 100 to 135 Vac.
4. Voltage Range Control Winding: 0.75 to 5 Vac inclusive.
5. Dependent Front-Back Contacts: Minimum of two.

2.03 NON-VITAL RELAYS (NORMAL DUTY)
A. Type: Plug-in.
B. Covers: Transparent plastic.
C. Relay Cabinet Covers: Shall permit viewing of relay contacts without disassembly.
D. Relay Indication: LED, mounted as part of relay, connected across coil to indicate relay is energized.
E. Non-Vital Relays: Capable of carrying 1 A (minimum) continuously without contact resistance exceeding 5 ohms.
F. Front-Back Contacts: Capable of breaking a load consisting of three vital or non-vital relays connected in parallel, at least 10,000,000 times without contact resistance exceeding 5 ohms measured at 10 milliamps.
G. Four dependent front-back contacts.

2.04 SPARE CONTACTS
A. Minimum of one spare dependent front-back relay contact per relay.

2.05 RELAY FUNCTION TYPES
A. Use vital relays for vital functions.
B. Use slow acting relays for slow pickup or slow release functions.
C. Use quick acting relays for quick pickup or quick release functions.
D. Use vital timer relays for timer delay functions.

2.06 RELAY BASES
A. Install in accordance with AREMA Communication and Signals, Part 6.2.2.
B. Individual conductors of case wire shall be crimped to each receptacle spring.
C. Insert receptacle spring into rear of appropriate plug board.

D. Vital relays, when inserted into front of relay bases, shall make direct contact with appropriate receptacle springs.

E. Wires shall not be soldered directly to receptacle springs.

2.07 TAGGING

A. Relays Shall Have Three Associated Tags.
   1. One tag showing relay name on card described above.
   2. Name on front and back of base/plugboard.
   3. Easily replaceable but shall not come off during normal service.

2.08 SPARE CONTACTS

A. Single Relay: Provide except for switch machine control relays.
B. Single Repeater Relay: Provide for either repeater relay or primary relay.
C. Multiple Repeater Relays: Provide for both final repeater relay and primary relay.

2.09 SOURCE QUALITY CONTROL

A. Tests and Inspections:
   1. Factory test vital relays in accordance with "shop" requirements of AREMA Communications and Signal Manual Part 6.4.1 (for dc relays) or Part 6.4.5 (for AC relays).
   2. Record pickup and drop-away values for vital relays on AREMA relay cards (AREMA Communications and Signal Manual Form 641-1 or AREMA Communications and Signal Manual Form 645-1) and submit to Resident Engineer.
   3. Use one AREMA relay card for each vital relay. Use cards shipped with relay.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Design system to eliminate use of both vital and non-vital relays to maximum extent possible through use of microprocessor based systems.

B. Provide and test relays required by Contractor's design, both vital and non-vital.

C. Repeat manufacturer's approved factory test procedure as described in Section 34 42 98, Signal System Testing, in the field, prior to installing relays in their final positions in wired racks.

D. Verify that each relay serial number, location, and relay name shown on cards corresponds to actual field conditions.

E. Plug non-vital relays into receptacles mounted on DIN rails in racks or cabinets.
F. Provide one normal and one reverse switch operating relay and a switch current overload relay for each switch and lock movement unless a vital solid state switch control module is used.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Design, procurement, installation, and testing of Signal Vital Processors, portable maintenance computer, and diagnostic and development tools.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. American Railway Engineering and Maintenance-of-Way Association Communications & Signal Manual of Recommended Practices (AREMA)
   a. Part 16 - Vital Circuit and Software Design

B. Abbreviations and Acronyms:

1. LCC – Link Control Center
2. PCB: Printed Circuit Boards
3. SVP: Signal Vital Processors
4. TCS: Train Control System – a portion of the LCC concerned with train control

1.03 SUBMITTALS

A. Submit:

1. Product Data:
   a. Description and catalog cut of proposed SVP to be furnished including proven equipment history.
   b. Complete technical data verifying that system proposed is in compliance with requirements of this Section.
   c. Catalog cut and manual for Application Firmware Testing and Development Tool. Rejection of testing and development tool is a rejection of entire SVP system.


3. Relay Equivalent Circuits:
   a. Convert application software, by automatic process, into relay equivalent circuits.
b. Depict application logic using standard drop line relay symbols such that an experienced signal person with no knowledge of ladder logic or Boolean algebra will be able to interpret programs.

c. Show circuits in normal position for drop line relay contacts up or down. Normal position is defined as signal system has no track occupancies, traffic circuits are in normal direction, interlocking signals are at stop, switches are in normal position, no speed restrictions are applied, no alarms, grade crossings not activated, and normal direction vent zone signals having proceed aspect.

d. Submit sample prior to writing of application programs.

e. Include logic including interface tables with design submittal for each location. In addition to interfaces to room wiring, interfaces include to LCC, other SVP in that location, SVP in adjacent locations, data I/O for LCP functions, data for recording, and data for track circuit speed command control.

4. Method of adjustment, maximum adjustable bits per second (BPS), and optimum adjusted BPS for non-vital communication ports.


6. Source Quality Control:

a. General: Section 34 42 98 – Signal System Testing identifies requirements for factory and field testing. Submit SVP testing documents under that Section.

B. Closeout Submittals:

1. As-Built SVP Logic:

a. Application format:

1) Can be burned on to SVP memory chip.

2) Can be modified using the application development tool.

b. Text Format:

1) Logic equations in alphabetical order.

2) Relay Equivalent Circuits.

3) All report assignments used for communications.

4) All I/O assignments,

5) Timer min/max /default settings.

6) Alphabetical index identifying page numbers for each equation.

c. Hard copy:

1) 3 ring binder.

d. Soft copies:
1) 3 copies
2) On CD or USB thumb drive
3) PDF text format and application format.

2. Record Documents: Include Relay Equivalent Circuits with as-built drawings for each location.

PART 2 - PRODUCTS

2.01 SVP SYSTEM DESIGN REQUIREMENTS

A. Manufacturers: Ansaldo STS, Alstom.
C. Provide same basic family of SVP for each location.
D. Design SVP system to control both vital and non-vital signal functions at interlockings, wayside signals, and locations requiring logic processing for Signal System.
E. Eliminate use of both vital and non-vital relays to maximum extent possible through use of SVPs; except where relays are designated in the typical circuits or specified for that function.
F. Base circuit design upon a single processor using closed loop principles for safety; however system design shall be a dual SVP units providing redundancy.
G. Functions required for system integrity evaluation, error logging, hardware interface, timing, data communication, application logic execution, and application of power to vital controller shall be fully integrated and executed by SVP. Failure to pass system integrity tests shall cause system to cease data communications and remove power form hardwire outputs in a completely failsafe manner.
H. Develop circuit design and application dependent software. Basis of dependent software design shall use existing ST nomenclature and logic structure.
I. Design SVPs with a complete set of input/output logic for the location.
J. Design each SVP with sufficient capacity for the signal functions at the location plus I/O – spare board capacity.
K. Failure of a vital controller component shall not cause vital interlocking system to fail to a less restrictive mode.
L. Off-line storage devices for operation or requirements for start-up are not allowed.
M. Program operation of system in solid-state non-vital memory.
N. Design adjacent SVPs to communicate via dark fiber.
O. Ensure signals display a restricted aspect rather than being dark in the event of a failure of both normal and standby processors.
P. Design SVP logic to place track blocks between adjacent interlockings upon cold start.
Q. SVP shall provide time stamp to signal equipment at each location including maintenance computers and event recorders to facilitate accurate event sequence reporting.
R. Signal Processor shall use Genisys protocol to talk to LCC in a manner compatible with the existing LCC to signal location interface. Use Genisys protocol time stamp from the Central Control Interface to synchronize the SVP time stamps.

S. Switch Locking: Vitally ensure that switches are locked even during a failure.

T. Provide a vital cutout relay if required.

U. SVP System Environmental Requirements.
   1. Operating Temperature Range: Minus 40 degrees F to plus 160 degrees F.
   2. Operating Humidity Range: 5 percent to 95 percent.

2.02 DUAL PROCESSORS
   A. Design system to be fully redundant with automatic failover.
   B. Redundant System Equipment: Including but not limited to SVP, dc power supplies, and modems for each serial port. For associated serial ports, redundancy may end at modems.
   C. Design a function to perform manual transfer between SVPs.
   D. Design system to automatically transfer to standby modem in the event of a communication failure. Vital communication between adjacent active SVPs shall be maintained via automatic processes. Design circuitry to prevent "hunting."
   E. Design dual SVP system to function as a warm standby.
   F. Warm Standby:
      1. Provide automatic transfer from normal to standby SVP units in the event of a failure. Transfer from standby to normal shall be a maintainer selection using a momentary toggle switch.
      2. Warm standby is only SVP logic and functions, relay circuits/functions do not need to be dual or normal and standby.
      3. Retain requests, controls, and indications when transfers between normal and standby occur. Data for blocks and other safety critical functions shall be hard wired to both the normal and standby SVP.
      4. Design system such that no delay or disruption to system functions occurs due to transfer.
      5. Ensure no unsafe conditions result from transferring between SVPs.
      6. Field equipment and TCS communications shall not be affected as a result of transferring between SVPs.
      7. Retain all Signal and Track Blocks applied.

2.03 PRINTED CIRCUIT BOARDS
   B. Vital Input/Output Boards:
1. Provide a sufficient number of PCBs in each SVP unit to accommodate vital hardwire inputs and outputs at the location.

2. Optically isolate inputs and output controls from power system internal to SVP unit.

3. Design I/O boards capable of controlling wayside devices, vital double break outputs, and other equipment from within signal room.

4. Design an I/O board able to directly control equipment with 110 Vac power.

5. Provide direct control of speed commands to track circuit transmitter.

6. Output Short: Capable of withstanding, without damage, shorting of output to opposite ac polarity, register short as an alarm.

7. Switch Machine Control: Driven via vital I/O board or vital relay.

8. Signal Control: Via vital relay only.

9. Spare I/O Capacity: Minimum 5 percent, and minimum two vital timers.

C. Non-Vital I/O Boards:

1. Design SVP units with non-vital input/output PCBs (NVI/NVO).

2. Design PCBs in SVP to accommodate non-vital hardwired inputs and outputs.

3. Spare I/O Points: Minimum 10 percent of total I/O points, Minimum of two of each type.

D. Expansion Boards:

1. Spare PCB Slots:

   a. Minimum of 1 of each type per SVP.

   b. At Terminal locations: Overlake Village, North Kirkland, and Lynwood, minimum of 3 of each type per SVP.

2.04 SVP PORTS

A. Design each SVP unit with vital and non-vital communications ports that interface with external devices and systems.

B. Vital Communication Ports:

1. Interfaces: SVPs within same location and at adjacent locations.

2. Port Type: RS232, RS485, or RS422.

3. The Contractor shall be allowed to propose Ethernet connections for vital communications only if his proposal can demonstrate:

   a. Vitality of the failure modes meeting AREMA requirements

   b. Redundancy of signal processor functions at each location is maintained.

   c. Communication failure faults shall isolate such that communication between no more than two locations occurs.
C. Non-vital Communication Ports:
   1. Interfaces: TCS system, SMC, portable maintenance computer, event recorder.
   2. Port Type: RS232, RS485, RS422, or Ethernet.
   3. TCS Connection: Ethernet or serial data with connection thru an Ethernet switch.

D. Port Indicator Light:
   1. Design for each Input, Output, and Input/Output PCB port.
   2. Ensure light is on when respective port is energized.
   3. Position indicator such that it is visible when viewing status lamps.

2.05 HARDWIRE INPUTS/OUTPUTS
A. Ensure hardwire inputs of vital controllers do not respond to ac voltage levels.
B. Design biased hardwire inputs not to respond to voltage of improper polarity under failure condition.
C. Design hardwire outputs of vital controllers with security equal to or greater than conventional double-break relay circuits.

2.06 SVP DIAGNOSTICS
A. Equip SVPs with diagnostics easily accessible to the user. Quickly and reliably identify failed printed circuit boards. Indicate cause and specific location of failures.
B. Design system to allow complete maintenance on normal or standby SVP without effecting signal operation in the area.
C. Design system to allow local testing, and diagnostics using application dependent firmware development system, signal room computer, or a laptop computer.
D. A processor health alarm from both normal and standby shall be reported to Link Control Center (LCC) and Local Control Panel (LCP) regardless of which processor is in control.

2.07 KEYING METHOD
A. Design system with a hardware and firmware keying method.
B. Design keying method to prevent SVP from operating with application dependent firmware designed for other vital controllers.
C. Ensure incorrectly installed PCBs render vital controller inoperable.
D. Include keying arrangement of card file on signal room drawings at each location
E. Display an error message if a card file is installed in an incorrect slot or location.
F. Key application dependent firmware to vital controller hardware rendering it impossible for application dependent firmware to be executed in a vital controller other than intended vital controller.
2.08 IDENTIFICATION
A. Design labeling system that is a part of unit to identify name of function associated with each I/O point.

B. Nomenclature:
   1. As shown in the Contract Documents.
   2. As defined for the existing ST installations.
   3. As defined in the AREMA Communication and Signals Manual of Recommended Practices signal standards.

2.09 SVP EXECUTIVE FIRMWARE
A. Store executive instructions in solid-state memory and refer to them as executive firmware.

B. Fully integrate and execute system integrity functions with a single SVP. Continuously test system integrity functions and generate an alarm for a failure.

C. Cease data communications and remove power from hardwire outputs in a completely fail safe manner upon detection of a failure of a system integrity function.

D. Log vital and non-vital failures and identify faulty PCB or function. Supervise a closed loop monitoring system for hardwire input and output functions. Include checks to ensure independence of inputs from one another.

E. Continuously ensure control over state of the following: Hardware outputs, RAM, vital data communications, spontaneous change in application dependent firmware.

F. System Integrity Functions: Error logging, hardware interface, timing, data communications, application logic execution, and application of power to vital controller.

2.10 APPLICATION DEPENDENT FIRMWARE
A. Store application dependent instructions in solid-state memory devices and refer to them as application dependent firmware.

B. Vital functions include, but are not limited to the following:
   1. Route check.
   2. Signal control.
   5. Approach locking.
   6. Detector locking.
   7. Route locking.
   8. Traffic locking.
   9. Indication locking.
  10. Switch control.
11. Switch indication.
12. Switch correspondence.
15. Track blocking.
16. Switch blocking.
17. Crossing warning functions.
18. Speed Command Selection including Temp Speed Controls
19. Data communication conditioning including building of repeaters.

C. Non-Vital Controls:
   1. Route request including switch operation and signal operation.
   2. Route cancellation.
   3. Auxiliary functions.

D. Non-Vital Indications:
   1. Signal indication.
   2. Switch position.
   3. Switch locked/unlocked.
   4. Route request/cancel.
   5. Track occupancy.
   6. Alarm and auxiliary status.
   7. System failure indications including communication.
   8. Crossing indications.

E. NVP Interfaces:
   1. TCS: See Section 34 42 65, Central Control Interface.
   2. Signal Maintenance Computer (SMC).
   3. Local Control Panels (LCP): See Section 34 42 69, Local Control Panels.

F. Software Timers: Externally settable in the field, selectable by a means other than by modification to application software, retain timer settings through power outages.

G. Application dependent firmware must be replaceable without disturbing executive firmware.
2.11 APPLICATION DEPENDENT Firmware DEVELOPMENT SYSTEM

A. Hardware and Software: Provide a laptop with the application development and testing system that is; capable of composition, debugging, graphical simulation, and solid-state memory storage of application dependent firmware.

B. Testing Tool:
   1. Capable of working with both vital and non-vital SVP software.
   2. Limits re-testing of application firmware after software modifications have been performed.
   3. Identifies revision level.
   4. Reports differences between revision levels.

C. Design system to include a standard text editor or word processor.

D. Version: Latest edition available from manufacturer of SVP, capable of modifying all software installed by the Contractor.

E. No copy protection schemes are allowed on system software.

F. Demonstrate hardware and software supplied with development system is completely compatible.

G. Hardware:
   1. PC or compatible.
   2. Color LCD flat panel monitor, 17 inch minimum.
   4. Highest speed DVD/CD ROM drive currently available.
   5. Minimum 250G hard disk drive in accordance with latest industry standards and approved by Sound Transit.
   6. Commercial off-the-shelf (COTS) hardware.

2.12 MEDIA CONVERTER


B. Output: Optical, full-duplex/half-duplex.

C. Baud Rate: Minimum 500Kbps.

D. Automatic baud rate detection.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Provide redundant, warm standby SVP system units for all locations that have CAB signaled track circuits and/or where signal logic is processed.
B. Provide media converters to connect adjacent SVPs using fiber.
C. Mount card files in standard 19 inch instrument racks.
D. Mount plug connectors, data transmission equipment, room computer, power supplies, power conditioning devices, terminal boards, wire connectors, and other equipment required to achieve a complete, stand-alone subsystem within a single instrument rack or on an adjacent rack with associated SVP units.
E. Mount card files and associated equipment in a manner that provides easy access to test points, indicators, and adjustments.
F. Mount SVP equipment between 1.5 feet and 5.5 feet above finished floor.
G. Mount SVP units to allow access from both front and rear.

3.02 IDENTIFICATION
A. Identify input and output ports on PCB by name assigned to the port in application firmware with a printed label.
B. Identify ports by slot and port numbers of PCB.

3.03 VARIABLE NOMENCLATURE
A. Variable nomenclature shall be the same as or match the nomenclature of the existing ST Link Signal System. The nomenclature of the existing system will be provided to the Contractor upon request.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:
   1. Procurement, installation, and testing of DC power supplies.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:
   1. National Fire Protection Association (NFPA)
      a. NFPA 70 National Electric Code (NEC)

1.03 SUBMITTALS

A. Submit:
   1. Product Data:
      a. Description and/or catalog cut of proposed DC power supplies to be furnished including proven equipment history.
      b. Include load calculations for each DC load in Section 34 42 35, Signal Power Distribution System, as part of total power consumption calculation.
   2. Testing Documents:
      a. General: Submit DC power supply testing documents under this Section.
      b. Certified Test Reports for factory testing.

PART 2 - PRODUCTS

2.01 DC POWER SUPPLIES

A. Mounting: Rack mountable.

B. Input Voltage Range: Between zero to 115 percent of rated voltage.

C. Housing: Panel-chassis combination with a perforated protective cover.

D. Environment: Zero degrees to 130 degrees F.

E. Outputs: One ammeter, one voltmeter, accessible on front panel.

F. Meter Accuracy: Plus or minus 2 percent with nominal voltage readings at center scale.
G. Terminal Posts: Input, output, and alarm circuits, insulated from frame.

2.02 GROUND DETECTORS

A. Leakage Current Detection: From either terminal of floating supply to ground, shorting or opening of a component part shall be detectable.

B. Leakage Path Resistance: Maximum 7,000 ohms.

C. Immune to the following:
   1. Transient current flows that may be the result of charging distributed supply-to-ground capacitances.
   2. Induced power line ripple which may exist between supply leads and ground.

D. Memory: Provide an indication of a momentary leakage condition, hold indication until reset by a push button.

E. Ground Detector Circuits: Meet fail-safe design criteria with respect to open circuits.

F. Environmental: Operates in a stable condition over specified temperature and voltage ranges specified for each power supply being monitored.

G. Test Switch: Three position, center off, momentary contact.


I. Indication Lights:
   1. Type: LED.
   2. Provide one white light to indicate that both buses are clear of grounds.
   3. Provide two red lights, one for each bus, to indicate that a ground has occurred on that bus.

PART 3 - EXECUTION

3.01 GENERAL

A. Provide electrical connection from power sources to associated DC power supply equipment, in accordance with National Electrical Code (NEC).

B. Provide DC regulated power supplies of each voltage necessary for Signal System equipment.

3.02 DC POWER SUPPLIES

A. Provide redundant DC power supplies for signal processors, relays, and circuits leaving the room.

B. Provide alarm contacts to indicate DC power supply failure.

C. Wire contacts of DC power supply alarms to non-vital processor for indications on SMC and inclusion in summary “power equipment failure” alarm to LCC.

D. Isolate power supply output from ground; do not ground positive or negative output terminals.
3.03 GROUND DETECTORS

A. Provide ground detection for any ungrounded system.

B. Design test switch to check operation of that detector, by providing momentary 7,000 ohm-to-ground leakage paths for dc buses being monitored.

C. Factory wire and mount ground detectors in relay racks.

D. Operation shall not interfere with operation of power or signal circuits or equipment.

E. Provide one independent isolated contact for remote indication of alarm condition.

F. Install ground in ground detecting part of circuits.

G. Check test ground versus prime ground for continuity.

END OF SECTION
SECTION 34 42 63
TRACK TRANSFORMERS

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:
   1. Procurement, installation, and testing of track transformers.

1.02 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

   1. American Railway Engineering and Maintenance-of-Way Association Communications & Signal Manual of Recommended Practices (AREMA)
      a. Part 14.2 - Electrical Devices
   2. National Electrical Manufacturers Association (NEMA)
      a. NEMA ST20 - Dry Type Transformers for General Applications

1.03 SUBMITTALS

A. Submit:
   1. Product Data: Description and catalog cut of each transformer including proven equipment history.
   2. Shop Drawings: Drawings, wiring diagrams, and performance data of transformers.
   3. Testing Documents:
      a. General: Submit documents in accordance with Section 01 95 00, System Testing and Integration. Submit track transformer testing documents under this Section.
      b. Certified Test Reports for factory testing.

PART 2 - PRODUCTS

2.01 BASIC CONSTRUCTION

C. Feeder Voltage Range: 100 V to 125 V.
D. Load Rating: 150 percent of maximum calculated load.
2.02 ELECTRICAL CHARACTERISTICS
   A. Voltage Output: 1 V to 15 V, in 1 V increments.
   B. Primary Excitation: 120 V, 100 Hz.
   C. Volt-Ampere Rating: Sufficient to handle operating load.
   D. Susceptibility: Not susceptible to dc saturation by propulsion currents.

PART 3 - EXECUTION

3.01 INSTALLATION
   A. Provide transformers for power frequency track circuits.
   B. Install transformers as shown on approved installation drawings.
   C. Rack mount the track transformers.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Design, procurement, and installation to assure electromagnetic compatibility (EMC).

1.02 REQUIREMENTS

A. Coordination:

1. Reduce susceptibility of or provide additional protection for signal equipment, if necessary, to prevent electromagnetic interference (EMI) from affecting operation of Signal System.

2. Work jointly with Sound Transit and others, designated by Sound Transit, to ensure compatibility among Signal System, LRVs, utility power lines, and other sources of electromagnetic interference.

1.03 REFERENCES

A. Reference Standards: This Section incorporates by reference the latest revisions of the following documents.

1. The American Public Transportation Association (APTA)
   a. APTA SS-E-010-98 – Standard for the Development of an Electromagnetic Compatibility Plan

1.04 SUBMITTALS

A. Submit:

1. EMC Control Plan.

2. EMI Susceptibility Data.

3. EMC Control Data.

PART 2 - PRODUCTS

2.01 PERFORMANCE / DESIGN CRITERIA

A. Design:

1. Ensure compatibility of Signal System and its elements with electrical environment, considering vehicles, traction power distribution system, and other sources of induced, conducted, and radiated interference.
2. Maximize electromagnetic interference rejection by Signal System in order to avoid both safety related and operational effects from such interference.

3. Interference sources include traction electrification system, LRV's propulsion and internal power equipment, and various non-LRT wayside sources.

B. Electromagnetic Interference and Compatibility:

1. Design and construct Signal System such that its equipment is not susceptible to and does not electrically interfere with safe and proper operation of LRVs or wayside equipment.

2. Design Signal System not to be susceptible to interference from LRVs variable frequency ac motor propulsion system.

3. Provide appropriate arresters, equalizers, and surge suppressors.

2.02 PLANS AND REPORTS

A. Plans and Reports are the method by which Contractor informs Resident Engineer of system compatibility. Plans and reports shall be in accordance with APTA SS-E-010-98.

B. EMC Control Plan:

1. Describe methods for ensuring electromagnetic compatibility between Signal System and other sources of electromagnetic interference.

2. In this document, describe Contractor’s plan for:

   a. Obtaining susceptibility data. Review Sound Transit furnished LRV EMI/EMC data for compatibility with signal system. This data does not cover every EMI source or sensitive device. The Contractor shall be responsible for gathering additional base line data.

3. Predicting expected levels of electromagnetic interference. Compare these with predicted susceptibility of signal equipment or sensitive non-signal equipment and assure the calculations (or measured values) demonstrate an adequate safety factor to the susceptibility levels. Include a composite susceptibility graph, considering conducted, radiated, and induced interference.

C. EMI Susceptibility Data:

1. Describe EMI levels below which signal equipment proposed will safely and reliably operate.

2. Data may be based on measured or calculated levels, but source and method of obtaining data shall be clearly described.

D. EMC Control Data:

1. Periodically present results of above control plan.

2. Data shall be accompanied by analyses of suspected interference difficulties and shall include suggested mitigating techniques both for Signal System and for source of interference.
PART 3 - EXECUTION

3.01 FIELD (SITE) QUALITY CONTROL
   
   A. Field Tests and Inspections:
      
      1. If the EMC control plan documents that some portion of the signal system can be susceptible to existing EMI levels, the Contractor shall prepare test procedures and perform field tests to demonstrate safe and reliable performance.

END OF SECTION
PART 1 - GENERAL

1.01 DESCRIPTION

A. This Section specifies the establishment and maintenance of a System Reliability Program, which shall be applied to obtain a valid assessment of the MTBF capabilities of the designated equipment and subsystems furnished under this Contract. This program shall include:

1. The furnishing of predicted design reliabilities.
2. Field reliability testing.
3. Continual comparisons of field reliability testing.
4. All corrective measures required to obtain satisfactory performance.

B. The equipment and subsystems to be tested for system reliability compliance shall consist of:

1. Microprocessor Based Interlocking.
2. Uninterruptible Power Supplies.
3. AF Track Circuits.
4. PF Track Circuit
5. Maintenance Computer
6. Switch Controller Unit
7. Switch Machine

C. The Contractor will be permitted to submit reliability data previously acquired from similar equipment and subsystems for predicted reliabilities. If equipment selected is identical to equipment satisfactorily used within the existing Sound Transit operating system, the requirements herein can be waived upon written acceptance from the Resident Engineer. The contractor shall submit this request in writing with the specifics of the equipment and where used on the existing Sound Transit system.

D. Field reliability testing shall be on a subsystem basis with the subsystem as defined above. The Contractor shall initiate the field reliability testing at Substantial Completion. The testing duration shall be one year. If there are no chargeable failures for a given component type within that year, the total hours shall be documented and the component shall be considered as passed. If Chargeable Failures have accumulated to the extent that the requirements for MTBF for the sub-system cannot be met, the demonstration period shall be extended in order to obtain the cycles/mean time between failure thresholds specified herein. In the event this causes the demonstration period to extend beyond Acceptance date for ST to start maintenance, the Sound Transit designated
personnel shall maintain equipment and collect field reliability data. The Contractor shall coordinate data collection and analysis with Sound Transit personnel.

1.02 SUBMITTALS

A. Reliability Program.

1. Within 180 days after award of the Contract, submit for approval the proposed reliability program plan. The program shall include, but not be limited to:

a. Organization and responsibilities of the proposed reliability effort.

b. Details of the design and component selection and screening processes proposed to be used to meet the reliability requirements.

c. Details of the procedures proposed to be used to calculate MTBF predictions.

d. Identification of the sources proposed to be used for component reliability data.

e. Proposed serialized type forms and reports, including preventive maintenance and discrepancy reports specifically for the joint use of the Contractor and Sound Transit during the field reliability assessment-testing program.

B. Predicted Reliability Reports.

1. The Contractor shall submit the predicted reliability study 60 days prior to component procurement. The report shall provide the predicted reliability for each of the included subsystems and propose an alternate design or equipment for the approval of Sound Transit, if areas of common failure appear inherent in the specified design mode or equipment.

2. Update the reliability report and re-issue each 180 days until design of the designated subsystems is complete. Indicate for each subsystem the estimated percent of design completion upon which the reliability prediction is made.

3. Include in the report, an analysis of items for which the prediction does not meet the reliability requirements or for which the prediction had changed significantly from the last report. Describe the corrective action proposed in this Section of the report for items predicted not to meet the reliability requirements.

4. Forward an updated report to Sound Transit whenever deviations of the predicted reliabilities are encountered during design (i.e., prior to production). If these reports indicate a marked decrease in predicted reliability, Sound Transit may require an alternate design or equipment change to increase predicted reliability to the requirements specified in the Table of Reliability Goals.

C. Reliability Testing Procedures.

1. Obtain from Sound Transit approval of detailed test procedures before field reliability assessment testing begins. The test procedures shall include, but not be limited to, the following details:

a. A listing of components by description, part number, and quantity comprising each line item in the Table of Reliability Goals.

b. Graphical sample presentation of the test plan and table to be used.
c. Burn-in (debugging) time.
d. Performance parameters to be measured.
e. Performance limits beyond which a failure has occurred.
f. Sample report and log forms to be used.

1.03 DEFINITIONS

A. The following definitions apply specifically to terms used in this Section.

1. Mean Time Between Failure (MTBF): The average time that the equipment will operate without a chargeable failure:

\[
\text{MTBF} = \frac{\text{Accumulated operating time of all units}}{\text{number of chargeable failures x number of units}}
\]


3. Minimum MCBF: The value specified in the Table of Reliability Requirements by Sound Transit for minimum number of switch throws without rejection. The switch throw count is an accumulation total independent of the switch locations doing the throwing.

\[
\text{MCBF} = \frac{\text{Accumulative number of switch throws}}{\text{number of chargeable failures}}
\]

B. Record and provide a written report of any malfunction or fault which prevents or limits equipment from performing its function in accordance with these requirements. Failure terminology and definitions as follows shall apply:

1. Chargeable Failure: All failures which require repair or replacement of a component or part are chargeable unless specified otherwise herein, or unless determined by Sound Transit to be caused by a condition external to the equipment under test. Failure due to workmanship deficiencies shall be counted as chargeable. Transient failures when proven to be caused by a single condition shall be counted only as a single failure. Also, transient conditions which temporarily prevent a function from being successfully performed shall be counted as chargeable failures unless it is shown that they are the result of external influences beyond the requirements of this Specification.

2. Non-Chargeable Failures: Failures which are proven to be the result of conditions exceeding those specified, (i.e., floods, derailments, vandalism, human error not normally protected against, etc.) shall be classed as non-chargeable and shall not be included in the reliability evaluation. Failure of parts installed by others (such as insulated joints, rails, normal and reserve ac power sources, etc.) that cause a dependent failure of the Contractor's equipment shall not be included in the reliability evaluation.
3. Failure Rate: The reciprocal of MTBF. For this reliability assessment program, the failure rate is assumed to be constant throughout the life of the equipment.

4. Independent Failure: A failure which will independently cause equipment performance outside of specified limits - one which occurs without being related to the failure of the associated items.

5. Dependent Failure: A failure of a part which is a direct result of an independent failure - one which is caused by the failure of an associated item(s). Dependent failures are non-chargeable failures.

6. Simultaneous Failure: In the event simultaneous or multiple failures occur, each failed part which will independently prevent satisfactory equipment performance shall be counted as an equipment failure.

1.04 CONSTRUCTION OF TABLE OF RELIABILITY GOALS

A. The Table of Reliability Goals is constructed of line items which represent identified subsystems. The specified table as constructed is shown at the end of this Section.

1.05 MATERIALS INVOLVED IN RELIABILITY PROGRAM

A. Each component in the reliability table shall individually demonstrate the predicted and demonstrated ability to meet it’s goals. The equipment considered part of each line item shall be as follows:

1. Microprocessor Based Interlocking.
   a. All equipment, wire, terminals, etc. starting at the input and ending at the function outputs. Major components including: signal processor with I/O including any serial or Ethernet data, plug connectors, component PC cards and connectors, capacitors, resistors, fuses, diodes, pushbuttons, switches, and data switching devices between redundant processors.

2. Uninterruptible Power Supplies.
   a. Assembly includes any breakers and switches on the assembly, rectifiers, inverters, by pass or isolation switches, or batteries that would keep the module from providing the required ac output for both conditions of ac input power is available or ac input power is not available.

3. AFTC Track Circuits.
   a. Includes both detection and cab signal function and track modules, impedance bonds, code selection interfaces and track relays (if used).
   b. Track module with loop couplers, direct cab signal injection modules, or other subassemblies designed to apply speed commands shall each count as the equivalent of a track circuit.

4. Power Frequency Track Circuit
   a. Includes 100 Hz Frequency Converter – As a separate MBTF.
   b. Includes the PF track transformers, resistors, vane relays, fuses, and miscellaneous components

5. Maintenance Computer
a. Includes the computer and monitor. The keyboard, and optical mouse are external to the computer and not part of the MTBF calculation.

6. Switch Control Module.

a. Includes the ability to control throw direction, current overload, and time of throw. This reliability is measured in switch throw cycles between failures. (i.e. MCBF) It will not be necessary to attach counters or do a comprehensive review of event recorder logs for an accurate count of switch throws. Estimation based on sampling of event recording logs or input from operations about the number of trains can be used for a throw count. The throw count does not need to be evenly balanced among switch machines.

7. Switch Machine. Includes the ability to control throw either direction. This reliability is measured in switch throw cycles between failures. (i.e. MCBF)

1.06 MAINTAINABILITY PROGRAM PLAN

1. Program Plan

a. Prepare and submit a Maintainability Program Plan.

b. Identify organization and responsibilities of key personnel that will assure maintenance planning are incorporated into design, component selection, and documentation.

c. The Program Plan shall identify that review of the manuals assures they contain:

1) The preventative maintenance tasks and recommended frequency for each assembly or subsystem are in the manual. If not in a standard component manual, then supplemental material identifying shall be provided.

2) Identification of recommended tools or diagnostic equipment has been made in the manual or supplemental material.

3) Detailed fault isolation and troubleshooting procedures are included in the manuals or are developed separately for inclusion in supplemental materials.

2. Maintenance Concept

a. Design and selection of components or subsystems shall provide early fault detection and rapid fault isolation to the proper service level to minimize costs and trouble shooting time.

b. There are 3 potential levels of maintenance; on-line, off-line, and bench. Trouble-shooting on-site and replacement to the Lowest Level Replacement Unit (LLRU) is the preferred method of repair.

c. The design and installation shall be checked to assure provisions for accessibility for maintenance tasks are incorporated. Without the RE’s specific permission, the installation shall not require movement of other equipment to access a replaceable part.
PART 2 - PRODUCTS

A. The product of this Section consists of the documents that establish and verify the reliability goals have been met as specified.

PART 3 - EXECUTION

3.01 ASSESSMENT PROGRAM

A. Verification that the equipment fulfills the reliability requirements described herein shall be per the approved reliability plan and as prescribed herein.

3.02 FIELD RELIABILITY DEMONSTRATION TESTING

1. The reliability of the various equipment types and sub-systems is specified in the Table of Reliability Goals. The minimum mean time between failures shall meet or exceed the reliability figures shown in the Table of Reliability Goals.

2. Modify or replace any subsystem or component part rejected by the reliability assessment program without additional cost to the Contract. Any such modification or replacement shall be subject to the approval of Sound Transit and subjected to the same reliability assessment program as the original equipment.

3. Reliability tests shall start and end as described in this section. Data collection shall be per device; per subsystem; for each location with MTBF results cumulative of all like devices.

3.03 TEST PREPARATIONS

A. The Contractor's personnel assigned to participate in field data collection for reliability testing shall be fully trained in their assigned tasks and be familiar with the approved reliability test plan. It is expected that these shall be the Contractor personnel assigned to maintain the Signal System until the Contractor's maintenance training class is completed.

B. The Contractor personnel assigned to evaluate reliability data, and supervise the overall execution of the reliability plan shall have performed a similar function for at least one prior major transit signals project.

3.04 ASSESSMENT REPORTS

A. Once the reliability demonstration test begins, submit reliability assessment report every three months showing comparison of field reliability testing results with accept-reject criteria for each line item in the Table of Reliability Goals.

3.05 FINAL DOCUMENTATION

A. Submit a final reliability assessment report upon completion of specified reliability testing.

3.06 FAILURE DOCUMENTATION

A. Report and formally record any malfunction or fault which prevents or limits equipment from performing its function. The report shall include:

1. Failure Rate.

2. Independent Failure.
3. Dependent Failure.
4. Simultaneous Failure.
5. Chargeable Failure
6. Non-chargeable Failure

3.07 PROCEDURE

A. Test Logs.
   1. The logs shall contain the following information:
      a. Identification of the component and subsystem by location, function, serial numbers (if applicable), and line item of Table of Reliability Goals to which the equipment is charged.
      b. Number of like components and subsystems in service.
      c. Date and time equipment was placed in service.
      d. Date and time of each failure.
      e. Cause of each failure.
      f. Classification of each failure (chargeable, not chargeable).
      g. All repairs and adjustments made and reasons for same.

B. Once each month, review the logs and make the following entries:
   1. Accumulated operating hours per line item.
   2. Accumulated chargeable failures per line item.

C. Preventive Maintenance.
   1. Preventive maintenance procedures specified in the approved operating and maintenance manuals for the equipment during normal operation shall be performed during the reliability testing period. Any additional preventative maintenance during the period of the Contractor’s maintenance responsibility shall be recorded and evaluated for their effect on the reliability test.
   2. Other maintenance actions required on behalf of other equipment such as troubleshooting, checkout, or downtime investigations shall be termed as preventive maintenance and classed as non-chargeable failures when performed in connection with reliability assessment.

D. Equipment Failure Record.
   1. Maintain a failure record for each line item. The record shall be designed to permit keeping of the entire test history of each line item on a single sheet so that behavior of the line items may be easily recognized. This record shall show all component failures for the line item.

E. Verifying Repair.
   1. Following repair or corrective action and prior to resumption of reliability testing, it shall be permissible to operate a maximum one week burn-in test to verify the
effectiveness of the repair. Failures and repair time during this period shall be recorded and reported but not used in determining compliance with MTBF requirements.

F. Corrective Action.

1. When any reliability test reaches a reject decision, the test will be discontinued for that line item. Immediately notify Sound Transit. Develop and propose a plan for correction of the deficiencies. Sound Transit will review such corrective action and may require handling as a design change or modification.

G. Failure Summary Record.

1. Maintain a failure summary record containing all the information needed to reach an accept/reject decision on the system under test. Make all entries directly and there shall be no need to process the data prior to an accept/reject decision. The summary shall include all component failures considered chargeable on all like equipment under test. The record shall present the current test status, including information on the total hours of test, failures, and MTBF of all units on test.

H. MTBF EVALUATION CRITERIA

1. Acceptance or rejection of equipment shall be on an individual function basis with the individual functions being the line items presented in the Table of Reliability Goals. Accept or reject decisions shall be based upon the procedures, formulae, and definitions specified herein. If test results fall short of the specified hours or cycles then the Contractor is required to propose a corrective action acceptable to Sound Transit that may include a redesign or selection of alternative equipment in the subsystem if necessary. An extension of the reliability demonstration test shall then restart to prove the corrective action was sufficient.

### TABLE OF RELIABILITY GOALS

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>MTBF Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Microprocessor Based Interlocking</td>
<td>36,000</td>
</tr>
<tr>
<td>2.</td>
<td>Uninterruptible Power System</td>
<td>40,000</td>
</tr>
<tr>
<td>3.</td>
<td>AFTC Track Circuit</td>
<td>50,000</td>
</tr>
<tr>
<td>4.</td>
<td>100 Hz Frequency Converter</td>
<td>120,000</td>
</tr>
<tr>
<td>5.</td>
<td>PF Track Circuit</td>
<td>60,000</td>
</tr>
<tr>
<td>6.</td>
<td>Maintenance Computer</td>
<td>50,000</td>
</tr>
<tr>
<td>7.</td>
<td>Switch Control Module</td>
<td>24,000 MCBF</td>
</tr>
<tr>
<td>8.</td>
<td>Switch Machine</td>
<td>24,000 MCBF</td>
</tr>
<tr>
<td>9.</td>
<td>DC Power Supplies</td>
<td>150,000</td>
</tr>
</tbody>
</table>

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section includes:

1. Requirements for Signal System factory testing, field testing, and field inspection.

1.02 REFERENCES

A. Reference Standards: Applicable provisions of the most recent adopted editions of the following standards shall apply to the work of this Section:

1. American Railway Engineering and Maintenance-of-Way Association (AREMA)
   b. C&S Part 6 - Communications and Signal Manual, Relays

2. Federal Railroad Administration (FRA)
   a. 49 CFR Part 236 - Rules, Standards, and Instructions Governing Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices, and Appliances

1.03 SUBMITTALS

A. Submit:

1. General: Submit signal system testing documents under this Section.

2. Test Program Plan: Submit for signal system testing.

3. Source Quality Control: Test Procedures and Test Results for each test.

4. Field Quality Control: Test Procedures and Test Results for each test.

1.04 TEST PROCEDURES

A. Guidance test procedures are available in appendix for Contractor’s use in creating their test procedures. These procedures are not created as a standard procedure that can be used without Contractor input and modification for the specific project, location, and/or application being tested. The Contractor retains the option to either independently create procedures or modify these. In either alternative the Contractor’s procedures shall verify all signal functions, both vital and non-vital for both typical locations with the guidance procedures as a minimum requirement. The Contractor shall also create procedures to verify any unique site specific functions.
PART 2 - PRODUCTS

2.01 SITE TEST EQUIPMENT AND MATERIALS

A. Test instruments and equipment used during tests shall be available, ready-for-use not less than 1 week in advance of test need.

B. Ready-for-use means properly matched for test parameters, properly calibrated, sufficiently supplied with leads, probes, adapters, and stands necessary to conduct the particular test in a completely professional manner.

C. Temporary or interim test related materials, special tools, connections, and jumpers, shall be furnished and available not less than one week in advance of test need.

D. Calibration Data.
   1. Document calibration date of each instrument used during each test.
   2. Calibration of each instrument must be certified by a recognized testing facility.
   3. Conduct recertification in accordance with manufacturer recommendations.
   4. Out-of-date instruments will be considered non-certified.
   5. Tests conducted with non-certified instruments will be rejected.

2.02 SOURCE QUALITY CONTROL

A. Factory Design and Production Tests:
   1. Prior to assembled factory rack testing the software shall undergo a simulator testing of functions including interlocking, speed command, Train to Wayside Communications (TWC) input, Local Control Panel (LCP) interface, and Train Control System (TCS) interface.

B. Factory System Tests:
   1. Relay racks and cases associated with a particular signal room must be inter-connected so as to function as one unit.
   2. Simulate and monitor external equipment such as signals, switch machines, switch locks, and TWC transponders during these tests. Where equipment is to be installed in existing locations simulate inputs from existing signal equipment during test of new equipment racks.
   3. Install relays and Signal Vital Processors (SVP) and non-vital processors (NVP) for this test.
   4. Ring-out factory wiring (continuity tested).
   5. Check and verify tagging.
   6. Perform a wire count to verify number of wires connected to terminal posts, relay plug board receptacle springs, and termination points are in accordance with approved circuit plans.
   7. Perform a complete circuit selection (breakdown) test on vital wiring.
8. Open each relay contact (separate openings for heel, front, and back contacts), observe that appropriate relays drop, and observe appropriate signal equipment responds as intended.

9. Perform operating tests to verify that factory wired relay racks function as intended.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. Field Installation Tests:

1. Relay Field Test:
   a. Test vital relays in accordance with "shop" requirements of AREMA Communications and Signal Manual Part 6.4.1 (for dc relays) or Part 6.4.5 (for ac relays).
   b. Record pickup and drop-away values for vital relays on AREMA relay cards (AREMA Communications and Signal Manual Form 641-1 or AREMA Communications and Signal Manual Form 645-1) and submit to Resident Engineer.
   c. Use one AREMA relay card for each vital relay. Use cards shipped with relay.
   d. Perform tests prescribed by AREMA Communications and Signals Manual of Recommended Practices, Part 2.4.1, where AREMA inspections and tests do not conflict with requirements of these Specifications.

2. Design tests to show proper operation of each major feature and function of each piece of signal equipment.

3. Prior to installation and after receipt on-site, inspect relays for shipping damage.

4. Wiring Check:
   a. Test each wire, cable conductor, and shield with a ringer or buzzer to identify both ends.
   b. Check tagging for conformity with approved circuit plans and exact termination points (relay name and contact number, terminal number, and equipment binding post).
   c. Apply a check mark to installation copy of circuit plans at each end of each wire tested at the time it is tested and found acceptable. This on-site test applies to wires and cable conductors.
   d. Point-to-point testing of rack wiring and tag verification required by this subsection, which is done at the factory, need not be repeated on-site provided:
      1) Contractor attests in writing that there have been no changes in rack wiring after completion of factory tests.
2) Contractor furnishes checked-off circuit plans required by this subsection.

   e. Perform a wire count to verify number of wires connected to each terminal post, relay plug board receptacle spring, and termination points is in accordance with approved circuit plans.

5. High Resistance Test:
   a. Use a 1000 V megger to determine insulation resistance of each underground cable conductor to ground and between conductors.
   b. A minimum of 5 megohms between each conductor and ground and between conductors is required.
   c. Disconnected or unplugged electronic devices or signal equipment and complete cable splices prior to testing.
   d. Follow test equipment manufacturer instructions for operation and electrical connections.
   e. Furnish data in a form which complies with FRA "Rules, Standards and Instructions for Railroad Signal Systems", CFR 49 Part 236.

6. Pre-fabricated Signal House Building Function Tests:
   a. Test the performance of any building equipment installed in the field. This may include heating or air conditioning, intrusion detection or access control, or fire detection.

7. Breakdown Test:
   a. Perform a complete circuit selection (breakdown) test of relay rack, line circuit, and circuit controller wiring.
   b. Each circuit shall, with circuit energized, have each circuit break point (termination, front contact, back contact, and heel contact.) individually opened by hand to determine that controlled device becomes de-energized with circuit opened and re-energized when test opening is reclosed.
   c. Apply a check mark to installation copy of circuit plans at each circuit break when test shows that it is effective.
   d. During this test, adjacent signal equipment rooms must be functional and connected.
   e. Breakdown tests of rack circuits performed in factory test do not need to be repeated in the field.
   f. In previously existing signal locations perform breakdown test on any circuit disturbed by modifications.

8. Energy Bus Test:
   a. Test energy bus with a 500 V megger, and ensure it is one megohm above ground minimum.
   b. De-energize high voltage buses when they are tested.
c. At interlockings, perform with each possible route lined up.

9. Power System Testing:
   a. Set power supplies and rectifiers to appropriate values.
   b. Record voltages and transformer tap settings on test report and on as-built circuit plans.
   c. Test signal power converters, power transfer equipment, power distribution equipment, UPS, UPS bypass, and signal power conductors to ensure system functions in accordance with specifications.
   d. Re-calculated spare capacity of power system using test data. Ensure test data calculations meet required operational UPS capacity according to Section 34 42 35, Signal Power Distribution System.

10. Check and adjust timers throughout system and record set values on test report and as-built circuit plans.

11. Test TWC interrogators and TWC system in accordance with manufacturer's recommendations.

12. Perform checks to determine corresponding track relay or device functioning as a track relay drops when a 0.20 ohm shunt is applied successively to each end and in the middle of each track circuit and at each end of fouling circuits. Record cab signal strength at the entering point of the track circuit meets specifications and verify it meets the requirements. Record the cab signal strength in cab signal loops and verify it meets the requirements.

13. Mainline Power Switches:
   a. Ensure signal protection is provided in the event a switch point is in a position other than full normal.
   b. A 1/4-inch gap, 6 inches from point-of-switch, between either switch point and stock rail causes signal governing movements over switch to display a "STOP" aspect, even if switch points are locked.
   c. Measurements over No. 1 switch rod for both normal and reverse positions of track switch points and ensure that:
      1) Switch point is obstructed 1/4 inch or more and switch and lock movement is manually or electrically operated, obstruction prevents switch-and-lock movement from locking and switch circuit controller indicates that switch is out of correspondence.
      2) Switch-and-lock movement circuit controller contacts are made, when switch point is within 1/8 inch closed. Do not perform test under power.
   d. Test mainline power switches to assure latchout mechanisms, clutches, and overload relays are functioning properly.
   e. Measure and record normal and obstructed switch currents.
   f. Check switch machines to determine locking dog cannot enter slot in lock rod with a 1/4-inch obstruction gauge between stock rail and switch point.
14. System Safety Performance:
   a. Perform test of routing safety functions including parallel route, approach locking, loss of shunt, overrun detection, traffic circuit and locking, and track circuit occupancies for signal clearing (both interlocking and vent zone).

15. Non-Vital Performance Testing
   a. Perform tests on non-vital interlocking functions such as route requests and alarms.
   b. Test local control panels, signal maintenance computers, portable maintenance computers, and event recorders to ensure they function as designed and meet performance requirements.

B. System Integrated Tests:
   1. Simulate movement of trains by applying shunt wires to track circuits and placing test TWC transponders over appropriate TWC loops.
   2. Design tests to determine that appropriate signal aspects are observed, appropriate cab signal currents are present, and cab signal coach lighting is operating as intended.
   3. During this test adjacent signal equipment rooms must be functional and connected.
   4. Observe appropriate signal aspects, for both conflicting and non-conflicting routes, are displayed and detector, approach, indication, and route locking are effective for interlocking routes.
   5. Test route request combinations.
   6. Design tests to ensure appropriate routes are granted.
   7. LRV Dynamic Tests:
      a. LRVs provided and operated by Sound Transit.
      b. Check routes and route requests, car clearance, and signal visibility.
      c. Check and record warning times and operations of joint operations merge.
      d. Speed Command/Continuous Cab Test:
         1) Verify speed commands are received throughout each route and section of track.
         2) Trains must traverse routes at an 8 mph maximum speed during test.
         3) Measure cab signal reception on LRV to verify no dead spots in reception.
         4) Sound Transit will provide test points to verify reception of cab frequency on vehicle ATP package.
      e. Pre-Shunt and Post-Shunt Tests:
1) Measure and record pre-shunt and post-shunt of each jointless track circuit while moving Sound Transit furnished trains slowly across track circuit boundaries.

2) This test may be combined with cab signal testing.

f. Cab Signal Tests.

1) Conduct with a Sound Transit furnished LRV and train operator.

2) Generate correct speed command and observe and verify command on LRV.

3) Ensure correct cab signal is received by LRV as shown on approved control line drawings.

8. Train Control System (TCS) Interface Integration Tests:

a. For integrated testing details see Section 01 95 00, System Testing and Integration. For controls and indications to be tested see Section 34 42 65, Central Control Interface

b. For tests designated as the Contractor’s responsibility, perform the test and request support from others if it is essential to complete the test. For integrated tests by others, provide support to verify combined system performance whenever LRV signals interface with other systems.

c. Provide personnel to monitor condition of signal equipment, align routes, observe LRV signals and other equipment during integrated testing when required.

d. Verify system logic provides integrated operation from Link Control Center (LCC) via TCS system.

e. As a prerequisite, verify serial data transmission to/from signal processors as matching approved code charts using a simulated LCC.

f. Provide personnel at signal room being tested for generating indications and verifying responses to LCC controls.

g. Perform a preliminary LCC to signal processor communications compatibility test for first room location installed.

9. Support Sound Transit testing activities in accordance with Section 01 95 00, System Testing and Integration.

END OF SECTION