SECTION 05 05 13
SHOP-APPLIED COATINGS FOR METAL

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:
1. Galvanizing where indicated for steel items.

B. Related Sections:
1. Section 05 12 00, Structural Steel Framing.
2. Section 05 50 00, Metal Fabrications.
3. Section 09 90 00, Painting and Coating.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
1. American Architectural Manufacturers Association (AAMA):
   a. AAMA 2604 Voluntary Specification, Performance Requirements and Test Procedures for High Performance Organic Coatings on Aluminum Extrusions and Panels
2. American Hot-Dip Galvanizers Association, Inc. (AHDGA)
   a. AHDGA Inspection Manual for Hot-Dip Galvanized Products
3. American Society for Testing and Material International (ASTM)
   a. ASTM A123/ A123M Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   b. ASTM A143 Safeguarding against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement
   c. ASTM A384 Safeguarding against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies
   d. ASTM A780 Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
   e. ASTM B6 Standard Specification for Zinc
4. Society for Surface Protective Coatings (SSPC)
   a. PA 1, "Paint Application Specification No. 1: Shop, Field, and Maintenance Painting of Steel,"
b. SP6 Commercial Blast Cleaning.

c. SP8 Pickling.

1.03 DEFINITIONS:

A. Hot-dip galvanizing: Dipping steel members and assemblies into molten zinc for lasting, or long-term corrosion protection. Resultant zinc coating fuses permanently with base steel material.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit data for shop primer and finish coats specified in Section 09 90 00, Painting and Coating, and 09 96 00, High-Performance Coatings.

1. Submit metal coatings product data in conjunction with the painting and coating or high performance coating submittals that are to be used to paint or coat the metal. This is to confirm that the shop applied steel primer is compatible with the intermediate coat and final paint coat. This submittal will not be considered complete and acceptable if either product is not compatible with each other.

C. Galvanizer Certification: Furnish signed certification for the following:

1. Membership in American Hot-Dip Galvanizers Association Inc.
2. Materials used in galvanizing and repair.
3. Methods used in galvanizing and repair.

D. Coordination Drawings: To safeguard against distortion, furnish to the galvanizer steel fabricator's shop drawings of non-standard fabrications, tubular fabrications, fabrications involving all dimension that exceed the size of the galvanizer's kettle and fabrications involving materials of different thicknesses.

1.05 QUALITY ASSURANCE

A. Galvanizing Firm:

1. Engage a galvanizing firm with a current membership in the American Hot-Dip Galvanizers Association Inc. (AHDGA).

2. Inspect and test galvanized fabrications in compliance with ASTM A123 for the following:

   a. Visual examination of samples and finished products.
   b. Thickness of coating
   c. Adhesion

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

B. DELIVERY, STORAGE, AND HANDLING:

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

A. Written warranty for five-year period starting on date of substantial completion stating that shop applied coating will not blister, peel, crack, chalk, change color or have other forms of degradation during the warranty period.

1. In the event that coating failure occurs within the warranty period, replace item indicating coating failure, including full cost of labor and materials for such replacement. Replacement items shall be new and finished with same type coating meeting the requirements of this Section. Replacement items shall match adjacent members.

2. Resident Engineer may, at his discretion, permit field repairs in lieu of replacement, provided the coating failure is minor in scope and the field repair material and method employed match its adjacent member.

PART 2 - PRODUCTS

2.01 GALVANIZING MATERIALS


B. Galvanizing Repair Paint: A three-part system using an organic zinc-rich primer, an epoxy or urethane intermediate coat, and a urethane topcoat.

2.02 PERFORMANCE REQUIREMENTS

A. Finish coating system shall meet or exceed the performance requirements of AAMA 2604 as outlined below. Refer to AAMA 2604 and the cited ASTM test procedures for more complete information on testing and exposure requirements.

1. Gloss: Coatings shall have 25 to 40 percent reflective gloss when tested in accordance with ASTM D523.

2. Dry Film Thickness: 1.6 mils minimum as measured by eddy current meter as defined in ASTM B244 or other equipment of equivalent precision.

3. Hardness: No rupture of coating film at F hardness minimum when tested by ASTM D3363.

4. Adhesion: No removal of coating film or blistering during dry, wet, or boiling water adhesion testing when tested in accordance with AAMA 2604: 7.4.1.

5. Impact Resistance: No removal of coating film when tested in accordance with AAMA 2604: 7.5.1.

6. Abrasion: Minimum abrasion coefficient value of 20, when tested in accordance with ASTM D968 and coefficient calculated in accordance with AAMA 2604.

7. Muriatic Acid Resistance: No blistering, and no visual change in appearance when tested in accordance with AAMA 2604: 7.7.2.1.

8. Mortar Resistance: Mortar test patches shall dislodge easily from the coating film and any residue shall be removable with a damp cloth or with 10 percent muriatic acid solution. No loss of film adhesion or visual change in coating appearance after removal of test patches when tested in accordance with AAMA 2604: 7.7.2.1.
9. Nitric Acid Resistance: Maximum color change of 5 NBS units between tested and untested areas as calculated in accordance with ASTM D2244, when tested in accordance with AAMA 2604: 7.7.3.1.

10. Detergent Resistance: No loss of adhesion or blistering and no visual change in appearance when tested in accordance with AAMA 2604: 7.7.4.1.

11. Humidity Resistance: Formation of blisters not to exceed "Few" blisters size No. 8, as shown in Figure 4, in ASTM D714 when tested in accordance with ASTM D2247 and AAMA 2604: 7.8.1.1.

12. Salt Spray Resistance: Maximum undercut failure of 1/16 inch at scribed test lines and maximum film failure rate of 2 percent by area due to blistering or other film failures when tested in accordance with ASTM B117 and with AAMA 2604: 7.8.2.

13. Weathering Resistance-Color Retention: Maximum color change of 5 NBS units between tested and untested areas as calculated in accordance with ASTM D2244 after exposure testing in accordance with AAMA 2604: 7.9.1.1.


15. Weathering Resistance-Gloss Retention: Minimum gloss retention of 30 percent when tested and calculated in accordance with ASTM D523 and AAMA 605.98 after exposure testing in accordance with AAMA 2604.

16. Weathering Resistance-Erosion Resistance: Maximum erosion of 10 percent of dry film thickness as measured by eddy current meter as defined in ASTM B244 or other equipment or equivalent precision after exposure testing in accord with AAMA 2604: 7.9.1.1.

B. Minor film scratches and other blemishes in film surfaces that are repaired in accordance with recommended procedures and with recommended touchup materials shall meet or exceed the performance requirements outlined below.

1. Such repairs shall match the original finish for color and gloss.

2. Such repairs shall adhere to the original finish and exhibit no removal of coating film or blistering during dry adhesion testing when tested in accordance with AAMA 2604: 7.4.1.1.

PART 3 - EXECUTION

3.01 PREPARATION FOR GALVANIZING

A. Galvanizing:

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 compliance with SSPC SP6, Commercial Blast Cleaning.

4. Pickle all surfaces in compliance with SSPC SP8, Pickling.
3.02 APPLICATION

A. Galvanizing:

1. Hot-dip galvanize in compliance 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 compliance with ASTM A143.

3. Safeguard against warpage or distortion in compliance with ASTM A384. Notify the Resident Engineer of potential warpage problems that require modification in design before proceeding with fabrications.

3.03 REPAIR OF GALVANIZING

A. Grind rough areas to produce a uniform surface.

B. Repair minor defects and coat masked areas in accordance with ASTM A780.

3.04 FIELD QUALITY CONTROL AND REPAIR

A. Galvanized Surfaces:

1. Apply galvanizing repair paint or other methods described in ASTM A 780.

2. Touch-Up Painting: Immediately after erection, clean field welds, bolted connections, and abraded areas of shop paint, and paint exposed areas with same material as used for shop painting. Apply by brush to provide a minimum dry film thickness of 3.0 mils.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for welding of structural steel and miscellaneous metalwork, including sheet steel, as indicated. This Section also includes qualification of welders and welding procedures, inspections and tests of welds.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 20 00, Concrete Reinforcing.
2. Section 05 50 00, Metal Fabrications.

1.02 REFERENCES

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

1. American Society for Nondestructive Testing (ASNT)
   a. Recommended Practice No. SNT-TC-1A

   a. ASTM E94 Guide for Radiographic Testing
   b. ASTM E164 Practice for Ultrasonic Contact Examination of Weldments
   c. ASTM E165 Standard Test Method for Liquid Penetrant Examination
   d. ASTM E709 Guide for Magnetic Particle Examination
   e. ASTM E1032 Method for Radiographic Examination of Weldments

3. 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 Specifications
   d. ANSI/AWS B1.10 Guide for the Nondestructive Examination of Welds
   e. ANSI/AWS D1.1 Structural Welding Code - Steel
   f. ANSI/AWS D1.3 Structural Welding Code - Sheet Steel
1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Make submittals in compliance with ANSI/AWS 2.4 and 3.0.

C. Welder Qualifications: Submit current Washington State Building Officials (WABO) welding certification for each welder, valid for each process, method, and position used.

D. Welding Procedures: Submit procedure qualification test records for procedures other than those pre-qualified in accordance with ANSI/AWS D1.1

E. Inspector Qualifications:
   1. Welding Inspector
   2. Personnel Performing Nondestructive Testing

F. Inspection and Test Reports: Forward inspection and test results to the Resident Engineer immediately after results are available. Results must state whether results are conforming or nonconforming.
   1. Visual inspection reports
   2. Ultrasonic test reports
   3. Nondestructive test reports

1.04 QUALITY ASSURANCE


B. Qualification of Welding Procedures: Prequalified or qualified in accordance with ANSI/AWS D1.1.

C. Qualifications of Welding Inspector: ANSI/AWS Certified Welding Inspector (CWI)

D. Qualification of Personnel Performing Nondestructive Testing:
   1. American Society for Nondestructive Testing Certified NDT
   2. 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.

E. Qualification of Stud-Connector Manufacturer: In accordance with ANSI/AWS D1.1, Annex IX, "Manufacturers' Stud Base Qualification Requirements."

PART 2 - PRODUCTS

2.01 MATERIALS

A. Fasteners
   1. High Strength Bolts
a. Bolt:  ASTM A325, Type 1, heavy-hex
b. Nuts:  ASTM A563 heavy-hex
c. Washers:  ASTM F436
d. Finish:  Hot-dip zinc coating per ASTM A153

2. Anchor Rods:  ASTM F1554, Grade 36

3. Weld Headed Studs:  ASTM A108, grades 1010 through 1020, headed stud type, cold finished carbon steel, AWS D1.1, Type B.

2.02 EQUIPMENT
A. Welding Rod/Electrodes for structural plate, shapes and bars.
   2. 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 requirements in conformance with ANSI/AWS D1.1.

2.03 FABRICATION
A. Welding of reinforcing steel for concrete is specified in Section 03 20 00, Concrete Reinforcing.

B. Shop Welding
   1. Perform shop welding as indicated in accordance with ANSI/AWS D1.1, and ANSI/AWS D1.3, as applicable to the work.
   2. Mark welder ID adjacent to completed weld using metal stamp, metal engraving, keel, paint stick, or other appropriate marking material.
   3. Weld stud shear connectors in conformance with stud manufacturer's printed instructions.

C. Anchorage to concrete:
   1. Refer to Section 05 50 00, Metal Fabrications.

2.04 SHOP WELD QUALITY CONTROL
A. Inspections and Test by the Contractor employed Independent Testing Laboratory
   1. Visual Inspection:
      a. Conform to ANSI/AWS D1.1.
      b. Visually inspect 100 percent of welds, for both permanent and temporary Work.
   2. Quality of welds and standards of acceptance: Conform to ANSI/AWS D1.1.

5. Ultrasonic Testing: ANSI/AWS D1.1, and ASTM E164, as applicable. Test complete joint penetration groove welds 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 1-1/2 inches.
   c. 100 percent for thickness greater than 1-1/2 inches.

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

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

8. Repairs: ANSI/AWS D1.1, Section 3.7. Reinspect or retest repaired or corrected welds as specified for the original weld.

B. Shop Inspections and Test by the Resident Engineer

1. All welds are subject to inspections and tests by the Resident Engineer. The Resident Engineer will inspect welds at random.

2. The Resident Engineer will make test results available to the Contractor, within 48 hours after inspection and testing.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL BY THE CONTRACTOR-EMPLOYED INDEPENDENT TESTING LABORATORY

A. Inspections and Tests

1. Perform tests of field welds as specified for shop welds in Shop Weld Quality Control article, herein, if applicable.

2. Prior to loading structures (permanent and temporary), successfully perform all required inspections and tests of structures in accordance with Contract Document requirements and notify the Resident Engineer of the results.

3. Allow Resident Engineer access to perform independent verification testing and inspection.

B. Field Welding: Perform field welding as herein specified for shop welding.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, fabricating, and erecting structural steel as indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 62 00, Non-Shrink Grouting
2. Section 05 05 13 Shop Applied Metal Coatings
3. Section 05 05 23, Metal Fastenings
4. Section 26 05 26 Grouting and Bonding for Electrical Systems
5. Section 26 42 50 Tunnel Corrosion Control at Stations

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
   b. AISC 360 Specification for Structural Steel Buildings

   a. ASTM A6 Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
   b. ASTM A36 Standard Specification for Carbon Structural Steel
   c. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   d. ASTM A252 Specification for Welded and Seamless Steel Pipe Piles
   e. ASTM A500 Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
   f. ASTM A572 Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
   g. ASTM A992 Specification for Structural Steel Shapes
   a. ANSI/AWS A2.4 Standard Symbols for Welding, Brazing, and Nondestructive Examination
   b. ANSI/AWS D1.1 Structural Welding Code-Steel
   c. ANSI/AWS D1.8 Structural Welding Code – Seismic Supplement

4. American Petroleum Institute (API)

5. Society for Protective Coatings (SSPC)
   a. SSPC-SP 6/NACE No. 3, Commercial Blast Cleaning

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. 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, and accessories, and erection sequence and details. Include procedures for heavy lifts and rigging.
   2. 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.
   3. 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.
   4. Indicate type, size, and length of bolts, distinguishing between shop and field bolts. Identify pretensioned and slip-critical high-strength bolted connections.
   5. Verify all dimensions and coordinate Work with adjoining Work.

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

D. 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.

E. 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/ASME SA36).

3. Statement that the steel was melted and rolled in the USA except for temporary steel struts and wales, and steelwork associated with the temporary decking structures.

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.

F. Records for steel pipe struts verifying fabrication, erection inspection, and nondestructive test conformance.

G. 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.

1.04 QUALITY ASSURANCE

A. Fabricator:

1. Currently certified under the AISC Certification Program, Category STD.

2. Minimum of five years experience with successfully completed structural steel work of similar complexity.

B. Erector

1. Currently certified under the AISC Certification Program, Category CSE

2. Minimum of five years experience with successfully completed structural steel work of similar complexity.

C. Professional Engineer: Licensed professional engineer currently registered in the State of Washington.
D. Welders: Section 05 05 23, Metal Fastenings
E. Welding Procedures: Section 05 05 23, Metal Fastenings

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle 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, in boxes, crates, or barrels, plainly marked 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.

PART 2 - PRODUCTS

2.01 STRUCTURAL STEEL SHAPES UNLESS NOTED OTHERWISE

A. Wide Flange Shapes (including structural tees): ASTM A992
B. Channels: ASTM A36
C. Angles: ASTM A36
D. Plate:
   1. Unless noted otherwise: ASTM A36
   2. Noted Grade 50: ASTM A572, Grade 50
E. Hollow Structural Sections
   1. Rectangular: ASTM A500, Grade B, Fy = 46 ksi.
   2. Round, diameter equal to or less than 20 inches: ASTM A500, Grade B, Fy = 42 ksi.

2.02 PIPE FOR PIPE CANOPY

A. ASTM A53, Grade B, Fy = 35 ksi.
   1. Each pipe shall be furnished with two ½-inch diameter holes (minimum) for grouting with one-way valves spaced every 3 feet along the pipe length. The two holes shall be located at either 3 and 9 o’clock positions or 12 and 6 o’clock positions staggered circumferentially along the pipe length.

2.03 PIPE FOR TEMPORARY STRUTS AND PSD CASING

A. ASTM A252 Grade 3 (modified) with a minimum yield strength of 50 ksi as modified by the following:
   1. Use straight seam welded, seamless, or helical (spiral) welded steel pipe. Make all welds complete joint penetration welds.
2. Manufacture steel pipe in conformance with the dimensional and fabrication tolerances indicated in API 5L, Chapter 7.

3. Use pipe of carbon equivalency (CE), as defined in AWS D1.1 no greater than 0.45.

4. Use steel pipe with steel sulfur content no greater than 0.05 percent.

B. Fabrication inspection requirements at the manufacturing plant are as follows:

1. For 25 percent of the length of each continuous longitudinal and spiral weld on each pipe, use nondestructive testing by either radiographic, radioscopic, real time imaging systems, or ultrasonic methods that are in conformance with the requirements of AWS D1.1 or API Specification 5L, Section 9.7 for PSL-1 pipe.

2. For 100 percent of the length of each circumferential butt splice weld joining lengths of pipe, use nondestructive testing by either radiographic, radioscopic, real time imaging systems, or ultrasonic methods that are in conformance with the requirements of AWS D1.1 or API Specification 5L, Section 9.7 for PSL-1 pipe.

3. Conform the acceptance and repair criteria to the requirements of AWS D1.1, for tension, cyclically-loaded, non-tubular connections, or API 5L for PSL-1 pipe.

4. If repairs are required in a portion of the weld, perform additional nondestructive testing on both sides of the repair for a length equal to 10 percent of the total length of the weld on the piece of pipe inspected. If additional weld defects are found, perform nondestructive testing on 100 percent of the length of the weld on the steel pipe in conformance with the procedures described above.

5. Be responsible for performing all fabrication and erection inspection at the manufacturing plant. Costs associated with such performance are incidental to furnishing the steel pipe.

6. Allow inspection to be witnessed by the Resident Engineer in conformance with the requirements of API Specification 5L, Appendix H as requested by the Resident Engineer.

7. Submit records verifying that testing was accomplished and tested welds were in conformance with these specifications with the manufacturer's mill certificates.

2.04 MANUFACTURED PRODUCTS

A. Bolts: Section 05 05 23, Metal Fastenings

B. Welding Electrodes: Section 05 05 23, Metal Fastenings

C. Grout: Section 03 62 00 Non-Shrink Grouting.

2.05 FABRICATION

A. Conform to the applicable requirements of AISC 303 and AISC 360.

B. 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.

C. Form and fabricate the work to meet installation conditions. Include accessories to adequately secure the work in place.
D. Seal joined members exposed to weather by continuous welds. Grind exposed welds smooth as indicated on the Contract Drawings.

E. Straighten rolled material, if necessary, before it is laid out for fabrication, in a manner conforming to the mill tolerances specified in ASTM A6, and by a process and in a manner which does injure the material. Sharp kinks and bends are cause material rejection. Do not use heat shrunk low-alloy structural steel.

F. 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. Perform flame cutting in such manner that metal being cut is not carrying stress. 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.

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

H. 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.

I. Bolt or weld connections as indicated.

J. Drill or punch holes at right angles to the surface of the metal and do not make or enlarge 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.

K. For items bearing on concrete, provide steel bearing plates and anchors as indicated. 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.

L. 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.

M. Include reinforcing angles, clip angles, plates, punched straps, brackets, and hangers as required to complete the work as indicated.

N. Provide drainage holes in structural components where water may accumulate without escape.

O. 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.

P. 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.
2.06 WELDING

A. Shop Welding and Shop Welding Repairs: Section 05 05 23, Metal Fastenings

2.07 BOLTING

A. Shop Bolting: Section 05 05 23, Metal Fastenings

2.08 SOURCE QUALITY CONTROL

A. Fabricator's Facility: Fabricator's shop or facility will be inspected before the start of fabrication work. Notify the Resident Engineer in writing at least ten days before the scheduled start of fabrication work.

B. Shop Welding Procedures and Personnel: Section 05 05 23, Metal Fastenings

C. Shop Welding and Weld Repair Testing and Inspection: Section 05 05 23, Metal Fastenings

D. Shop Bolting Testing and Inspection: Section 05 05 23, Metal Fastenings

PART 3 - EXECUTION

3.01 ERECTION


B. 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.

C. 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 building.

D. Temporary Bracing: Provide temporary bracing as required and keep in position until final completion. Brace and carefully handled 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.

E. Bases and Bearing Plates


2. Set base and bearing plates for structural members on wedges, shims, or setting nuts as required for correct leveling.

3. Weld plate washers to top of base plate.

4. Snug-tighten anchor rods after supported members have been positioned and plumbed. Do not remove wedges or shims but, if protruding, cut off flush with edge of base or bearing plate.
5. Install high-strength, non-shrink grout in conformance with Section 03 62 00, Non-Shrink Grouting

F. Erection and Assembly: After erection and field assembly, align the various members forming parts of the completed structure and adjust accurately before fastening. Conform to tolerances of AISC 303.

G. Splice members only where indicated. Fasten splices of compression members after bringing abutting surfaces completely into contact.

H. Do not use thermal cutting during erection unless approved by the Resident Engineer. Finish thermally cut sections within smoothness limits in AWS D1.1. Cutting will be permitted only on secondary members which are not under stress, as acceptable to the Resident Engineer.

I. 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.

J. Erection Connections
   1. Place holes, plates, or other attachments required by the erector so as not to interfere with or cause any other detrimental affect 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.

3.02 WELDING
   A. Field Welding and Field Welding Repairs: Section 05 05 23, Metal Fastenings

3.03 BOLTING
   A. Field Bolting: Section 05 05 23, Metal Fastenings

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: Section 05 05 23, Metal Fastenings
B. Field Welding and Weld Repair Testing and Inspection: Section 05 05 23, Metal Fastenings
C. Field Bolting Testing and Inspection: Section 05 05 23, Metal Fastenings

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for, but is not limited to: all miscellaneous shop-fabricated ferrous metal and aluminum work indicated or otherwise required to complete the work, except as otherwise indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 30 00, Cast-in-Place Concrete.
2. Section 03 62 00, Non-Shrink Grouting.
3. Section 03-15 25 Anchorage to Concrete.
4. Section 05 05 13, Shop Applied Coatings for Metal.
5. Section 05 05 23, Metal Fastenings.
6. Section 05 12 00, Structural Steel Framing.
7. Section 09 90 00, Painting and Coating.

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)
g. **ASTM A 500** - Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes; 2003a.

h. **ASTM A 653** – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process; 2009.

2. **American Welding Society (AWS)**

1.03 **SUBMITTALS**

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Provide data on manufactured products; describe materials and finish, product criteria, limitations.

C. Shop Drawings: Indicate profiles, sizes, connection attachments, reinforcing, anchorage, size and type of fasteners, and accessories. Include erection drawings, elevations, and details where applicable. Provide templates for anchors and bolts specified for installation under other sections.

   1. Indicate welded connections using standard AWS A2.4 welding symbols. Indicate net weld lengths.

D. Certifications:

   1. Welders and welding procedures: Submit certifications as specified in Section 05 05 23, Metal Fastenings.

1.04 **QUALITY ASSURANCE**

A. Fabricator: Company specializing in manufacturing the types of products specified in this section, and with minimum five years of documented experience.

B. Installer: Company specializing in performing the work of this section with minimum four years of experience.

C. See Section 05 05 23, Metal Fastenings for requirements for welders, welding procedures, and inspections.

D. Design Metal Fabrications under direct supervision of a Professional Structural Engineer experienced in design of this Work and licensed in the State of Washington. Include structural computations, material properties, and other information needed for structural analysis that has been signed and sealed by the engineer.

1.05 **PROJECT CONDITIONS**

A. Field Measurements: Check actual locations of walls and other construction work which metal fabrications must fit, by accurate field measurements before fabrication; show recorded measurements on final shop drawings. Coordinate fabrication, delivery and installation schedule with construction progress to avoid delay of work.

   1. Where field measurements cannot be made without delaying the Work, guarantee dimensions and proceed with fabrication of products without field measurements. Coordinate construction with work of other trades to ensure that
actual dimensions correspond to guaranteed dimensions. Allow for fitting and trimming.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Metal Surfaces
   1. For metal fabrications exposed to view upon completion of the Work, provide materials selected for their surface flatness, smoothness, and freedom from surface blemishes. Do not use materials whose exposed surfaces exhibit pitting, seam marks, roller marks, rolled trade names, roughness, and, for steel sheet, variations in flatness exceeding those permitted by referenced standards for stretcher-leveled sheet.

B. Steel
   1. Wide Flange Shapes (including structural tees): ASTM A992
   2. Channels: ASTM A36
   3. Angles: ASTM A36
   4. Plate:
      a. Unless noted otherwise: ASTM A36
      b. Noted Grade 50: ASTM A572, Grade 50
   5. Hollow Structural Sections
      a. Rectangular: ASTM A500, Grade B, Fy = 46 ksi.
      b. Round, diameter equal to or less than 20 inches: ASTM A500, Grade B, Fy = 42 ksi.

C. Stainless Steel
   1. Bar Stock: ASTM A 276, Type 316 . Type 316 Active for exterior applications.
   2. Plate: ASTM A 167, Type 302 or 316 Type 316 active for exterior applications.
   3. Rolled Shapes: ASTM A 276, Type 316 Type 316 Active for exterior applications.
   4. Finishes: All exposed stainless steel to be No. 4: Random Orbital Finish.

D. Grout and Anchoring Cement
   1. Non-shrink-non-metallic Grout: Specified in Section 03 62 00, Non-Shrink Grouting.

E. Fasteners
   1. Provide zinc-coated fasteners for exterior use or where built into exterior walls. Select fasteners for the type, grade, and class required.
2. Bolts and Nuts: Regular hexagon head type ASTM A 307 Grade A.
3. Lag Bolts: Square Head type: FS FF-B-561.
5. Wood Screws: Flat head carbon steel FS FF-S-111
6. Plain Washers: Round, carbon steel FS FF W 92
7. Expansion Anchors: FS FF-S-325 type 1 (internally threaded tubular expansion anchors) and machine bolts in accordance with FS FF B 575 grade 5.
8. Neoprene Washers and Sheet Spacers: Flat, hard neoprene, minimum 1/8-inch thickness or as required to totally separate dissimilar metal materials.

2.02 FABRICATION

A. Form metal fabrications from materials of size thickness, and shapes indicated but not less than sizes required to comply with performance requirements indicated. Work to dimensions indicated, using proven details of fabrication and support. Use type of materials indicated or specified for various components of each metal fabrication.

B. Form exposed work true to line and level with accurate angles and surfaces and straight, sharp edges.

C. Allow for thermal movement resulting from the following maximum change in ambient temperature in the design, fabrication, and installation of installed metal assemblies to prevent buckling, opening up of joints, and overstressing of welds and fasteners. Base design calculations on actual surface temperatures of metals due to both solar heat gain and nighttime sky heat loss.

1. Temperature Change (Range): 100 degrees F

D. Shear and punch metals cleanly and accurately. Remove burrs.

E. Ease exposed edges to a radius of approximately 1/32 inch unless otherwise indicated. Form bent-metal corners to the smallest radius possible without causing grain separation or otherwise impairing the work.

F. Remove sharp or rough areas on exposed traffic surfaces.

G. Weld corners and seams continuously to comply with AWS recommendations and the following:

1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.

2. Obtain fusion without undercut or overlap.

3. Remove welding flux immediately.

4. At exposed connections, finish exposed welds and surfaces smooth and blended so that no roughness shows after finishing and contour of welded surface matches those adjacent.

5. On all steel members exposed to exterior, weld all joints and seams continuously all around to prevent moisture penetration of joints or seams.
H. Fit and shop assemble items in largest practical sections, for delivery to site. Minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Use connections that maintain structural value of joined pieces. Clearly mark units for reassembly and coordinated installation.

I. Fabricate items with joints tightly fitted and secured.

J. Continuously seal joined members by intermittent welds and plastic filler.

K. Grind exposed joints flush and smooth with adjacent finish surface. Make exposed joints butt tight, flush, and hairline. Ease exposed edges to small uniform radius.

L. Exposed Mechanical Fastenings: Flush countersunk screws or bolts; unobtrusively located; consistent with design of component, except where specifically noted otherwise.

M. Supply components required for anchorage of fabrications. Fabricate anchors and related components of same material and finish as fabrication, except where specifically noted otherwise.

N. Fabrication Tolerances

1. Squareness: 1/8 inch maximum difference in diagonal measurements.


5. Maximum Deviation from Plane: 1/16 inch in 48 inches.

2.03 FINISHES

A. Steel: See Section 05 05 13, Shop Applied Coatings for Metal.

1. Hot-dip galvanize all steel fabrications not scheduled for a paint finish unless noted otherwise.

2. Primer paint finish is required at all other steel surfaces.

B. Aluminum: See Section 05 05 14, Fluoropolymer Coatings.

1. High Performance Organic Coating System: AAMA 2604 multiple coat, thermally-cured fluoropolymer Hylar 500 or Kynar 500 system; color as selected from manufacturer's standard colors.

PART 3 - EXECUTION

3.01 EXAMINATION

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

1. Check elevations of concrete- and masonry-bearing surfaces and locations of anchor rods, bearing plates, and other embedments for compliance with requirements.

B. Proceed with installation only after unsatisfactory conditions have been corrected.
3.02 PREPARATION
A. Clean and strip primed steel items to bare metal where site welding is required.
B. Supply setting templates to the appropriate entities for steel items required to be cast into concrete or embedded in masonry.

3.03 ERECTION
A. Tolerances
1. Maximum Variation from Plumb: 1/4 inch per story, non-cumulative.

3.04 INSTALLATION
A. Install items plumb and level, accurately fitted, free from distortion or defects.
B. Provide anchorage devices and fasteners where necessary for securing miscellaneous metal fabrications to in-place construction; include threaded fasteners for concrete and masonry inserts, toggle bolts, through-bolts, lag bolts, wood screws, and other connections as required.
C. Perform cutting, drilling, and fitting required for installation of 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.
D. Provide temporary bracing or anchors in formwork for items that are to be built into concrete masonry or similar construction.
E. Fit exposed connections accurately together to form hairline joints. Weld connections that are not to be left as exposed joints, but cannot be shop welded because of shipping size limitations. Do not weld, cut, or abrade the surfaces of exterior units which have been hot-dip galvanized after fabrication, and are intended for bolted or screwed field connections.
F. Field Welding: Comply with AWS Code for procedures of manual shielded metal-arc welding, appearance and quality of welds made, methods used in correcting welding work, and the following:
   1. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
   2. Obtain fusion without undercut or overlap
   3. Remove welding flux immediately.
   4. At exposed connections, finish exposed welds and surfaces smooth and blended so that no roughness shows after finishing and contour of welded surface matches those adjacent.
G. Coat concealed surfaces of aluminum, steel and stainless steel that will come into contact with grout, concrete, masonry, wood, or dissimilar metals, with a heavy coat of bituminous paint.
H. Provide for erection loads, and for sufficient temporary bracing to maintain true alignment until completion of erection and installation of permanent attachments.


1. Set loose leveling and bearing plates on wedges or other adjustable devices. After the bearing members have been positioned and plumbed, tighten the anchor bolts. Do not remove wedges or shims, but if protruding, cut off flush with the edge of the bearing plate before packing with grout. Use non-metallic non-shrink grout. Pack grout solidly between bearing surfaces and plates to ensure that no voids remain.

J. Toilet Partition and other overhead supports: Anchor supports securely to, and rigidly brace from overhead building structure.

K. Bar Gratings: Comply with NAAMM grating standard for bar sizes, installation clearances, and standard anchoring details.

1. Secure removable units to supporting members with type and size of clips and fasteners indicated, or if not indicated as recommended by grating manufacturer for type of installation conditions shown.

2. Secure non-removable units to supporting members by welding where both materials are the same; otherwise, fasten by bolting as indicated above.

3. Attach toe plates to gratings by welding at locations indicated.

L. Bollards: Anchor bollards in concrete by means of pipe sleeves preset and anchored into concrete. After bollards have been inserted into sleeves, fill annular space between bollard and sleeve solid with non-shrink, non-metallic grout, mixed and placed to comply with grout manufacturer's directions.

M. Install items plumb and level, accurately fitted, free from distortion or defects.

N. Provide for erection loads, and for sufficient temporary bracing to maintain true alignment until completion of erection and installation of permanent attachments.

O. Perform field welding in accordance with AWS D1.1.

P. Bearing Assemblies:

1. Install bearing assemblies in conformance with manufacturer's written directions.

2. Protect bearing assemblies until all Work is complete in conformance with manufacturer's written directions.

Q. Obtain written approval from Resident Engineer prior to site cutting or making adjustments not scheduled.

3.05 ADJUSTING

A. Obtain approval prior to site cutting or making adjustments not scheduled.
3.06 CLEANING

A. After erection, clean field welds, abrasions, and surfaces not shop primed or galvanized, in accordance with Section 05 05 13, Shop Applied Coatings for Metals.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing galvanized steel handrails within the running tunnels.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 15 25, Anchorage to Concrete.
2. Section 03 62 00, Non-Shrink Grouting.
3. Section 05 05 13, Shop Applied Coatings for Metal.
4. Section 05 05 23, Metal Fastenings.

1.02 REFERENCES

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

B. American Society for Testing and Materials (ASTM)
   a. ASTM A36 Specification for Structural Steel
   b. ASTM A53 Specification for Pipe, Steel, Black and Hot-Dipped, Zinc Coated, Welded and Seamless

2. National Association of Architectural Metals Manufacturers (NAAMM)
   a. ANSI/NAAMM AMP S21 Pipe Railing Manual

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings: Detailed drawings of metal handrails and railings, showing sizes, details of fabrication and construction, handrail brackets, locations of hardware, anchors, and accessories, and installation details.

C. Product Data: Manufacturers' Product Data of railing system and railing components, handrails, handrail brackets, accessories, and anchors. Include manufacturer’s written instructions for storage, handling, and installation.

D. Fabricator qualifications and experience.

E. Installer qualifications and experience.

F. Source Quality Control inspection tests and reports.
G. Field Quality Control inspection tests and reports.

1.04 QUALITY ASSURANCE

A. Fabricator: Experienced and skilled in the custom fabrication of architectural metal handrails and railings.

B. Installer: Experienced and skilled in the installation of custom architectural metal handrails and railings.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Include fittings and components, sleeves, hardware, backing plates, and accessories as required for complete and finished handrail installations.

B. Metal Handrails

1. Steel Pipe: ASTM A53, Type S, Grade A, of diameters and sizes indicated. Instruct pipe manufacturer to furnish Architectural Handrail Grade pipe.

2. Anchor Plates: ASTM A36

3. Welding Rod/Electrodes: Section 05 05 23, Metal Fastenings

4. Bolts: Section 05 05 23, Metal Fastenings

5. Concrete Anchors

   a. Conform to Section 03 15 25, Anchorage to Concrete.

   b. Where cast-in anchors are not included in the concrete construction, provide stainless steel expansion anchors with matching stainless steel bolts or studs with nuts, of sizes as indicated or required.

   c. Use adhesive anchors on concrete curbs or along a concrete edge or concrete joint to prevent spalling.

   d. Provide washers under bolt heads and nuts.

C. Grout: Section 03 62 00, Non-Shrink Grouting

2.02 FABRICATION

A. General

1. Prefabricate and shop-assemble metal handrails as far as practicable.

2. Make handrails continuous. Where continuous handrails are required to be interrupted by equipment or cross passages, provide horizontal handrail returns to the wall and complete with end caps.

3. Form changes in rail direction by radius elbows.

4. Precision-form bends in rails to a smooth continuous radius. Finish work to a quality true to detail. Create butt joints with an internal pipe sleeve or dowel.
5. Grind and dress welded joints of handrails and railings to smoothly match adjacent surfaces and maintain the shape and profile of the item welded.

6. Cut material square and remove burrs from exposed edges with no chamfer.

7. Make exposed joints butt tight and flush.

8. Close exposed ends of pipe/handrail by use of appropriate end caps.

B. Welding: Section 05 05 23, Metal Fastenings

C. Finishes: Hot-dip galvanize all metal handrail and brackets in conformance with Section 05 05 13, Shop Applied Coatings for Metal.

2.03 SOURCE QUALITY CONTROL

A. Shop Welding: Section 05 05 23, Metal Fastenings

B. Shop Galvanizing: Section 05 05 13, Shop Applied Coatings for Metal

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Install in locations indicated on Contract Drawings.

2. Install in conformance with the approved Shop Drawings and ANSI/NAAMM AMP S21 as applicable.

3. Install concrete anchors in compliance with Section 03 15 25, Anchorage to Concrete.

4. Install metal handrails and accessories as required for complete and finished installation.

5. Erect work square and level, horizontal or parallel to rake of tunnel walkway, and free from distortion or defects detrimental to appearance or performance.

6. Provide expansion joints as needed to allow for thermal expansion or contraction.

7. Grind and polish welds smooth to match adjacent finish surfaces.

B. Field Welding: Section 05 05 23, Metal Fastenings

3.02 REPAIR/RESTORATION

A. Repair damaged galvanized surfaces in conformance with Section 05 05 13, Shop Applied Coatings for Metal.
3.03 FIELD QUALITY CONTROL

A. Field Welding: Section 05 05 23, Metal Fastenings

B. Field Galvanizing: Section 05 05 13, Shop Applied Coatings for Metal

END OF SECTION
SECTION 06 82 00
GLASS-FIBER-REINFORCED PLASTIC

PART 1 - GENERAL

1.01 SUMMARY
A. This section includes specifications for Glass Fiber Reinforced Plastic (GFRP) reinforcement utilized for the Tunnel Boring Machine (TBM) break-in and break-out zones at Roosevelt Station and Brooklyn Station.

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

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Manufacturer’s Product Data:
  1. Chemical and physical properties
  2. Delivery, storage, and handling instructions
C. Manufacturer’s Certified Test Reports:
   1. Source quality control testing for chemical and physical properties performed by and independent testing laboratory.
   2. Submit reports for each bar size and each type of resin matrix used.
D. Placing Drawings: Include bar lists, schedules, placing details, plans, and elevations as required to delineate this portion of the work.

1.04 DELIVERY, STORAGE, AND HANDLING
A. Deliver, store, and handle GFRP bars in compliance with manufacturer’s published instructions.
B. Do not store GFRP bars directly on the ground. Use blocks to keep bars free of dirt, mud, and other foreign objects.
C. Store GFRP bars under cover to avoid direct sunlight and chemical substances.
PART 2 - PRODUCTS

2.01 MATERIALS

A. GFRP Reinforcement for soil nail wall shotcrete facing:

1. Surface: Deformed and sand coated.

2. Fiber Reinforcement: Continuous glass fibers with a minimum volume fraction of 65 percent per ASTM D2584. Glass fibers shall be either S or E glass.

3. Tensile Properties: Comply with Table 06 82 00.A. Tensile properties shall be determined in accordance with ASTM D3916 and ASTM D2990.

<table>
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<tr>
<th>Bar Size</th>
<th>Tensile Strength (kilopounds per square Inch(ksi))</th>
<th>Allowable Tensile Stress (Working Stress Limit) (ksi)</th>
<th>Tensile Modulus of Elasticity (ksi)</th>
<th>Ultimate Strain in Tension (percent)</th>
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<td>1.7</td>
</tr>
</tbody>
</table>

4. Binding material: Composed of vinyl ester resin, which is homogenous throughout the cross section of the bar and has a maximum volume fraction of 35 percent.

5. Manufacturing Process:
   a. Pultrusion process.
   b. Glass roving to be drawn through a resin bath, surface undulations and sand to be applied prior to thermoset of the polymer resin.


B. GFRP Soil Nail Elements

1. Surface: Deformed, sand coated or both.

2. Fiber Reinforcement: Continuous glass fibers with a minimum volume fraction of 65 percent per ASTM D2584. Glass fibers shall be either S or E glass.

3. Tensile Properties: GFRP soil nail elements shall have an allowable tensile capacity of no less than 40 kips. GFRP soil nail elements shall be capable of sustaining the allowable tensile strength for a minimum of 5 years. The elements shall be capable of sustaining twice the allowable tensile strength for a minimum of 2 days. The tensile properties shall be determined in accordance with ASTM D3916 and ASTM D2990.
4. Binding material: Composed of vinyl ester resin, which is homogenous throughout the cross section of the bar and has a maximum volume fraction of 35 percent.

5. GFRP soil nail elements shall be Durglass ED72 flat elements or approved equal.

6. GFRP soil nail heads shall be capable of sustaining loads of at least 35 kips.

7. GFRP soil nail elements shall not be spliced.

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

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify Work is ready to receive GFRP bars prior to installation.

3.02 PLACEMENT

A. Unless otherwise indicated, place reinforcing bars in accordance with CRSI Manual of Standard Practice. Conform to placement tolerances allowable limits in ACI 117.

B. Include all reinforcing bar details as required by CRSI when not indicated on the Contract Drawings or explicitly referred to in the Contract Specifications.

C. Securing:

1. Secure bars to prevent displacement by workers and shotcrete.

2. Secure GFRP bars at one-half the distance specified for steel reinforcing.

D. Cleaning: Remove foreign substances from bars before installation.

3.03 FIELD QUALITY CONTROL

A. Field Bending: Do not field bend GFRP bars.

B. Field Cutting:

1. Field cut GFRP bars with a high speed grinding cutter or saw.

2. Do not shear GFRP bars.

END OF SECTION
SECTION 07 10 00
WATERPROOFING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies furnishing and installing the permanent waterproofing system for cross passages.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15 Portland Cement Concrete
2. Section 31 74 19.05 Shotcrete for SEM Tunnels
3. Section 31 74 19.10, Initial Shotcrete Tunnel Lining
4. Section 31 74 19.20, Final Shotcrete Tunnel Lining

1.02 REFERENCES

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

1. American Society for Testing and Materials (ASTM)
   a. ASTM D374 Test Method for Thickness of Solid Electrical Insulation
   b. ASTM D568 Test Method for Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position
   c. ASTM D638 Test Method of Tensile Properties of Plastics
   d. ASTM D1593 Specification for Nonrigid Vinyl Chloride Plastic Sheeting
   e. ASTM D1621 (Mod.) Compressive Properties of Rigid Cellular Plastics
   f. ASTM D1777 Method for Measuring Thickness of Textile Materials
   g. ASTM D1785 Specification for Polyvinyl Chloride (PVC) Plastic Pipe, Schedules 40, 80, and 120
   h. ASTM D3776 Test Methods for Mass per Unit Area (Weight) of Woven Fabric
   i. ASTM D3786 Test Method for Hydraulic Bursting Strength of Knitted Goods and Non-woven Fabrics: Diaphragm Bursting Strength Tester Method
   j. ASTM D4533 Test Method of Trapezoid Tearing Strength of Geotextiles
k. ASTM D4632 Testing Method for Breaking Load and Elongation of Geotextiles (Grab Method)

1.03 DEFINITIONS

A. Control and Grouting Pipes: Pipes installed near water barrier intersections. If leakage should occur the pipes are used for remedial grouting.

B. Cross Passage Type: Either typical cross passage configuration or cross passages 21 and 31, low point pump station cross passages, as indicated in the Contract Documents.

C. Double Weld: Machine welded seams achieved by use of automatic hot-double-wedge welding equipment.

D. Geodrain: Composite panel providing a groundwater channel and protection of the synthetic membrane from sharp projections on the surface to which membrane is applied.

E. Geotextile: Non-woven fabric providing groundwater drainage channel and protection of the Membrane from sharp projections of the shotcrete surface to which the Membrane is to be applied.

F. Leakage: Damp spots, water seeping or dripping from the final tunnel lining or tunnel invert.

G. Membrane: Synthetic waterproofing membrane specifically formulated for sealing underground structures against intruding groundwater.

H. Patent Strip: Channel shaped stainless steel bar with pre-punched holes used to achieve a tight fit at waterproofing terminations.

I. Protective Concrete: Concrete placed on waterproofing installed at the tunnel invert to prevent damage.

J. Regroutable Hose: Hose attached to water barriers or to the TBM segment at waterproofing terminations as shown in the Contract Documents which must be grouted, flushed and regrooted with polyurethane grout.

K. Sealant Strip: Polymer swelling gasket strip applied in conjunction with patent strips at waterproofing terminations.

L. Sectioning: Water barriers arranged to seal off individual membrane sections. Used in conjunction with control and grouting pipes.

M. Single Weld: Hand welded seam consisting of a tack weld, a thin continuous weld and a rolled end weld. Single seams are sealed with liquid PVC at membrane welds.

N. Temporary Relief Pipe: Temporary groundwater relief pipe installed as needed in the invert or tunnel side walls as needed to relieve groundwater pressure during construction.

O. WA Anchor: Rigid PVC shell with an inside thread and PVC membrane flange used to aid in creating watertight penetrations through the membrane for temporary steel rod attachment.

P. Water Barrier: A base seal waterstop welded to the membrane.
Q. **Waterproofing**: Layered system consisting of membrane, geotextile or geodrain, concrete protection layers, water barriers, grouting pipes and regroutable hoses, and various other sealing products, combined which prevent intrusion of groundwater into the interior of the finished structures.

1.04 SYSTEM REQUIREMENTS

A. PERFORMANCE REQUIREMENTS

1. No water leakage into the finish structure shall be acceptable.

1.05 SUBMITTALS

A. Qualifications including a resume listing applicable project experience, position held, duration and project description.

1. Waterproofing installer
2. Waterproofing supervisor

B. Product Data for the Following: Include, where applicable, catalogue cuts, MSDS sheets, certification of compliance, manufacturers recommendations for storage, handling, installation and protection, testing, welding, detection for damage and repair:

1. Geotextile
2. Geodrain
3. Membrane
4. Water barrier
5. WA anchor
6. Patent strip
7. Sealant strip
8. Perforated pipe
9. Remedial grout
10. Regroutable hose

C. Shop Drawings. Include plans, sections and details showing as a minimum:

1. Sequence of waterproofing installation relative to construction sequence.
2. Typical sheet layouts for each type of cross passage. Include splice locations and types of welds.
3. Build-up of layered waterproofing in invert and at initial shotcrete tunnel lining.
4. Layout of water barriers for sectioning including location of control and grouting pipes and regroutable hoses.
5. Layout of regroutable hoses and junction boxes with labeling system to identify each hose and its location as well as fixing and termination of hoses.
6. Waterproofing terminations at the TBM tunnels.
7. Waterproofing at penetrations including but not limited to electrical ducts, mechanical pipes, and sleeves.
8. Waterproofing at corners,
9. Rebar support at reinforced tunnel sections.
10. Attachment assembly.
11. Control and grouting pipe assembly including protection from concrete, shotcrete, and grout intrusion during concrete pours, shotcrete application, and contact grouting.

D. Waterproofing Protection Plan, narrative and details describing the procedures to prevent damage during construction operations such as installation of formwork, reinforcement and embedded items, placement of concrete, application of shotcrete.

E. Waterproofing installer certification from the membrane supplier

F. Material Samples:
2. Geodrain: One square foot.
3. Membrane: One square foot including double welded seam one foot long.
4. Attachment assembly: Three each.
5. Water barrier: One foot length welded to membrane.
6. Control and grouting pipe: One foot length (including flange).
7. Silicone paste: Two four ounces jars.
8. WA Anchor: One each (including threaded rod).
10. Polymer sealant strip: One foot length.
11. Remedial grout: Two four ounces jars.
12. Regroutable hose: One foot length.

G. Field Samples:
1. Double weld samples, three feet long, from each double wedge welding machine, prior to the start of daily shift.
2. Prepare and submit field samples daily prior to seam welding.
H. Reports/Records/Forms:
1. Surface Acceptance Form completed and signed prior to start of installation.
2. Waterproofing Installation Acceptance Form completed and signed immediately after completion of an installation/testing area.
3. Test (including Re-Tests) and Repair Reports

I. As-built drawings:
1. Control and grouting pipes:
   a. Location and elevation of control and grouting pipes.
   b. Date of pipe installation.
   c. Date of concreting.
   d. Names of workers and supervisors for respective work.
   e. Water barriers: Location and elevation of water barriers and size of sections.
2. Regroutable hose:
   a. Location and elevation of junction boxes, where regroutable hoses start and terminate.
   b. Location and elevation of regroutable hoses.
   c. Labeling system to correspond with labels attached to hoses in the field.

J. Leak Remediation Plan:
1. Submit leak remediation plan prior to the start of any work associated with stopping leakage through a completed cross passage lining.
2. Include product data for all material and equipment proposed, narrative outlining procedures and stages for grouting, coordination with other work, location, as-built locations of the water barriers within the area of sectioning targeted, and the details associated with grouting and cleaning regroutable hoses.

1.06 QUALITY ASSURANCE

A. Waterproofing supervisor shall have a minimum five years experience in the installation of waterproofing systems for underground structures using membrane and associated waterproofing materials indicated.

B. Waterproofing Installer shall be trained for installation and testing operations proposed, and have a minimum of five years of experience in the installation of flexible membranes in underground waterproofing installations.

C. Perform test welding, using the membrane and equipment planned for the production work, for all types of welds. Perform and test the welds in the presence of the Resident Engineer prior to production installation.

D. READINESS REVIEW MEETINGS:
1. Before installation of waterproofing and concrete final lining over same, meet at project site with waterproofing installer, waterproofing installation supervisor, and other entities concerned with waterproofing installation performance, and Resident Engineer.

2. Record discussions and agreements and furnish copy to each participant.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver materials and products in labeled packages.

B. Store, and handle materials and products in strict accordance with manufacturer's instructions, recommendations, and material safety data sheets.

1. Place material on smooth surface free of rocks or other protrusions which may damage the material.

2. Protect from damage from sunlight, weather, excessive temperatures, and construction operations.

3. Remove damaged material from the site and dispose of in accordance with applicable regulations.

C. Store all flammable materials in a cool, dry area distant from sparks and open flames.

1.08 SITE CONDITIONS

A. Refer to Geotechnical Baseline Report

B. Provide sufficient access to Resident Engineer during installation of waterproofing system, to allow for inspection of the work.

C. Install waterproofing at shotcrete surfaces only after the surface is in compliance with smoothness criteria shown on the Contract Drawings and has been accepted by the waterproofing installer and Resident Engineer in writing.

D. Prior to waterproofing installation, prove the absence of any continuing and significant deflection or increase of stress.

E. Prior to geotextile installation, place a four foot wide strip of geodrain at low point of invert to allow water seepage through shotcrete, and construction water to drain to pump sump.

F. Collect all seepage through shotcrete with geodrain of required width and connect to geodrain placed in invert.

1.09 WARRANTY

A. The Contractor shall provide a warranty for the water tightness of the structure up to two years beyond the final contract completion date.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Geotextile: Non-woven polypropylene geotextile of uniform thickness and surface texture with the following minimum physical properties and testing methods:

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>VALUES</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>285 mil</td>
<td>ASTM D 1777</td>
</tr>
<tr>
<td>Unit Weight</td>
<td>22 oz./sq yd.</td>
<td>ASTM D 3776</td>
</tr>
<tr>
<td>Grab Tensile Strength</td>
<td>285 lbs.</td>
<td>ASTM D 4632</td>
</tr>
<tr>
<td>Elongation</td>
<td>85 percent</td>
<td>ASTM D 4632</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>135 lbs.</td>
<td>ASTM D 4533</td>
</tr>
<tr>
<td>Burst Strength</td>
<td>400 psi</td>
<td>ASTM D 3786</td>
</tr>
<tr>
<td>Chemical Resistance</td>
<td>pH-value 2 to 13</td>
<td></td>
</tr>
</tbody>
</table>

B. Geodrain: Composite panel consisting of a rigid drain core and filter fabric bonded on one side with the following minimum physical properties and testing methods:

1. Fabric

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>VALUES</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Weight</td>
<td>4 oz./sq yd.</td>
<td>ASTM D 3776</td>
</tr>
<tr>
<td>Grab Tensile Strength</td>
<td>110 lbs</td>
<td>ASTM D 4632</td>
</tr>
<tr>
<td>Elongation</td>
<td>60 percent</td>
<td>ASTM D 4632</td>
</tr>
<tr>
<td>Trapezoid Tear Strength</td>
<td>50 lbs.</td>
<td>ASTM D 4533</td>
</tr>
<tr>
<td>Burst Strength</td>
<td>215 psi</td>
<td>ASTM D 3786</td>
</tr>
</tbody>
</table>

a. Core Properties:

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>VALUES</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>0.45 inch</td>
<td>ASTM D 3776</td>
</tr>
<tr>
<td>Compressive Strength</td>
<td>15,000 psi</td>
<td>ASTM D 1621 (Mod.)</td>
</tr>
<tr>
<td>Flow Capacity</td>
<td>15 gpm/ft.</td>
<td>ASTM D 4716</td>
</tr>
</tbody>
</table>
C. Membrane: Polyvinyl chloride (PVC), waterproofing membrane or approved equal, of uniform thickness and surface texture. PVC membrane non-reinforced with the following minimum physical properties under respective testing methods:

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>VALUES</th>
<th>TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>Tunnels &amp; Shafts: 80 mil</td>
<td>ASTM D 374</td>
</tr>
<tr>
<td>Ultimate Tensile Strength</td>
<td>2200 psi</td>
<td>ASTM D 638</td>
</tr>
<tr>
<td>Ultimate Elongation</td>
<td>230 percent</td>
<td>ASTM D638</td>
</tr>
<tr>
<td>Low Temperature Impact</td>
<td>pass @ -20 degrees F</td>
<td>ASTM D1593</td>
</tr>
<tr>
<td>Chemical Resistance</td>
<td>pH-value 2 to 13</td>
<td></td>
</tr>
<tr>
<td>Flammability</td>
<td>self extinguishing</td>
<td>ASTM D 568</td>
</tr>
</tbody>
</table>

D. Attachments: Membrane attachment disk manufactured of membrane compatible material with minimum 3-inch diameter with one steel washer embedded in disk. Attachment of disks with min. 1-1/4 inch nails.

E. Water Barrier: Continuous PVC strip weldable to membrane with embedment ribs of the following minimum dimensions:

1. 16-inch width with six ribs of 1.0-inch minimum rib height (including base).
2. Intersections pre-fabricated on site or by manufacturer.

F. Control and Grouting Pipes: 1-inch nominal pipe size polyvinyl chloride (PVC) pipe schedule 40; ASTM D1785, length as shown on the Contract Drawings. Where visible in public areas provide with inside thread and removable cap.

G. WA Anchor:

1. Rigid PVC shell with inside thread and 12 inches diameter compatible flange for attachment to waterproofing membrane.
2. Rigid PVC shell minimum 8-inches long with outside grooves and 5/8-inch diameter inside thread for application of threaded steel rod.

H. Epoxy resin: Compatible with WA Anchor, and suitable for use in grouting it in place prior to attachment to membrane.

I. Protective Concrete: Refer to Section 03 05 15 Portland Cement Concrete, Table 03 05 15.A – Class 3000A.

J. Temporary Relief Pipe: 1-inch to 8-inch nominal size polyvinyl chloride (PVC) pipe Schedule 40, ASTM D 1785; each with fitted cap.

K. Patent Strip: 14 gage channel shaped stainless steel bar, 1 inch wide, pre-punched one inch on center, used at membrane termination.

L. Sealant Strip: Polymer based seal, designed to undergo controlled expansion in the presence of moisture, Type Duroseal Expansion Waterstop, by BBZ or approved equal.

1. Minimum dimensions: 0.8 inch wide by 0.4 inch thick.
2. Designed to perform in salt water and shall have a water pressure resistance of 75 psi.

3. Compatible with membrane.

M. Perforated Pipe: 4-inch nominal diameter, flexible, corrugated, perforated pipe with circumferential perforations, Type N12 by Advanced Drain Systems, Incorporated or approved equal.

N. Regroutable Hose: FUKO Type II, by BBZ USA, Inc. or approved equal.

   1. Minimum 3/4-inch outside diameter, consisting of a solid core with lateral openings covered by neoprene strips and the entire system wrapped with a wide mesh, suitable for injection with resin grouts.
   2. Equipped with color coded injection and ventilation ends, closure plugs and anchoring system.
   3. Anchoring system shall not puncture the waterproofing membrane.

O. Junction Box: Heavy duty plastic box with removable cover compatible with the regroutable hose system and of sufficient size to accommodate injection and ventilation ends of hoses.

P. Remedial grout: Duroseal Inject 2000 by BBZ, HA Flex LV by DeNeef, or approved equal.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prepare surfaces which receive Membrane according to the criteria specified herein and shown in the Contract Drawings.

   1. All surfaces shall be free of oils, grease, and gasoline.
   2. Repair all joints, offsets, voids, cracks and spalled areas which are greater than one half inch in width or depth with quick setting grout, mortar, or approved equal.
   3. Remove all loose shotcrete, concrete, and debris.
   4. Cut off and patch all projecting portions of dowels, flush with the face of the shotcrete surface and remove temporary supports and hangers installed in shotcrete lining for construction purposes. Any protrusions of more than ½ inch shall be covered with shotcrete, quick setting grout, or mortar such that no sharp edges are observed.
   5. Cover embedded elements in concrete and shotcrete with a minimum 1 inch of shotcrete prior to installing geotextile and membrane.
   6. Cover steel fiber reinforced shotcrete (if used) with plain shotcrete with a minimum thickness of 1.5 inch prior to waterproofing installation.
   7. Prepare shotcrete surface in accordance with smoothness criteria specified in Section 31 71 23, Excavation by Sequential Excavation Method, and shown in
the Contract Drawings with the exception of the invert, where a level surface has to be provided to avoid standing water.

8. Repair damaged or spalled surfaces, voids, and cracks having depths greater than one half inch with shotcrete, quick setting grout, mortar, or equal.

9. Place a four foot wide strip of geodrain at low point of cross passage invert to allow water seepage through shotcrete and construction water to drain to pump sump.

10. Collect seepage through shotcrete with geodrain connect to geodrain placed in invert.

B. Surface Inspection and Acceptance:

1. Inspect all surfaces to which waterproofing will be applied to, in the presence of the Waterproofing Installer and the Resident Engineer.

2. Correct deficiencies identified during inspection, and re-inspect after corrective action has been taken.

3. Complete Surface Acceptance Forms to release an area for waterproofing installation, and obtain the waterproofing supervisor, waterproofing installer engineer, and Resident Engineer’s signatures on the Surface Acceptance Form.

4. Distribute signed Surface Acceptance Forms in accordance with Specification Section 01 45 00, Quality Control.

3.02 INSTALLATION

A. Install waterproofing at shotcrete surfaces only after Surface Acceptance Form has been signed by the Resident Engineer.

B. Install Waterproofing as soon as practical following completion of Surface Acceptance Form, and prior to any work which might damage the membrane.

C. Installation of geotextile, geodrain, and membrane:

1. Attachment:
   a. Place attachment assemblies in surface depressions to achieve tight fit of geotextile.
   b. Provide attachments on side walls and roof of cross passages at maximum 2-foot centers horizontally and vertically. At inverts, provide attachment as required. Provide a uniformly snug fit to receiving surfaces.

2. Geotextile and geodrain
   a. Place geotextile prior to the installation of waterproofing membrane.
   b. Place continuous 4-foot wide panels of geodrain at the following locations prior to the installation of geotextile:
      1) At cross passage invert centerline to allow seepage and construction water to drain to pump sump after membrane and protective concrete are in place.
2) At longitudinal wall/invert joints.

3) At radial joint invert joints (if used).

4) At all locations in arch where significant seepage is noticeable, For baseline purposes, assume one seepage location per Cross Passage.

3. Membrane:
   a. Install membrane with sufficient overlap for welding. Trim overlap if necessary to achieve snug fit.
   b. Use radial seams for cross passage walls and arch.
   c. Use longitudinal seams within invert and at arch/invert splice.
   d. Provide double wedge welded seams unless otherwise approved.
   e. Test all welds as specified.

4. Installation of water barriers for sectioning:
   a. Install at locations and elevations indicated on the Contract Drawings.
   b. Weld to membrane with one single weld on each side.
   c. Clean from dirt, debris, concrete, and shotcrete.

D. Installation of control and grouting pipes:
   1. Install as shown on the Contract Drawings prior to concrete lining placement.
   2. Arrange location of control and grouting pipes to avoid interference with rebar or embedments.
   3. Protect control and grouting pipes during concrete lining pour from damage.

E. Installation of regroutable hoses:
   1. Install regroutable Hoses in the horizontal and radial water barriers as shown on the Contract Drawings.
   2. Fasten regroutable hose with membrane straps to hold the hose in place during application of concrete or shotcrete.
   3. Install junction boxes near the tunnel cross passage interface to receive and hold regroutable injection hoses and ventilation ends of hoses, as indicated.
   4. Protect junction boxes and the hoses associated with them from damage during concrete pours.
   5. Provide a labeling system for regroutable hoses and maintain written records of their locations for inclusion on the As-Built drawings.

F. Protect membrane during installation and concrete lining:
   1. Protect invert waterproofing by placing protective concrete over it as soon as practical after installation.
2. Do not drill holes through concrete that has been placed over membrane.

3. Where reinforcement is required, utilize WA anchors to affix or otherwise stabilize reinforcement prior to concrete placement, and provide a 2-inch minimum continuous spacing between membrane and rebar.

4. Relieve water build-up behind membrane through use of drainage pipes or and pumps, prior to concrete pours.

5. Check integrity of waterproofing during installation of rebar, formwork, and during pouring concrete and application of shotcrete.
   a. Note location of any breach, damaged areas, or potentially damaged membrane on as-built drawings.
   b. Repair immediately any damage to membrane, prior to placement of concrete over it.

6. Do not penetrate waterproofing for other than permanent purposes with approved methods or temporary purposes authorized by the Resident Engineer.

7. Do not allow construction debris or equipment to accumulate on the waterproofing membrane.

3.03 FIELD QUALITY CONTROL

A. Installation inspection shall confirm or otherwise document the following:
   1. Use of specified materials.
   2. Proper storing and handling of material.
   3. Ambient temperature.
   4. Adequate supervision by waterproofing supervisor.
   5. Seam direction and layout as shown on shop drawings.
   6. Number and layout of attachments.
   7. Overlap of membrane at seams for welding.
   8. Application of welds as specified.
   9. Penetrations are performed as shown on shop drawings.
   10. Location, type, and elevation of water barriers. Provide as-built documentation as specified.
   11. Location and elevation of grouting pipes. Provide as-built documentation as specified.
   12. Location and elevation of regroutable hoses and junction boxes. Provide as-built documentation as specified.
   13. Installation of protective layer.

B. TESTING OF MEMBRANE WELDS:
1. **General:**
   a. Perform tests in the presence of Resident Engineer.
   b. Perform tests as installation progresses. Repair and retest seams that fail before continuing installation.
   c. Maintain records of test results, repairs, and retesting every time an installation section is completed. Retain on site, and provide copies to the Resident Engineer upon request.

2. **Double welds:** Perform test by applying internal air pressure between seams as follows:
   a. Test Pressure: 30 psi.
   b. Hold pressure for 10 minutes.
   c. Acceptance Criteria: Air pressure loss shall be less than 10 percent after 10 minutes.

3. **Single weld including corners and water barriers:**
   a. Check all welds for continuity by either of the following inspection methods. Single welds at membrane splices or patches to be tested prior to the application of liquid PVC:
      1) Run a rounded screwdriver along the joint after the weld has cooled.
      2) Blow stream of air under high pressure against the weld and observe opening of the weld. Re-weld and test any discontinuity.
      3) Replace or repair sections of the membrane determined to be defective.

3.04 **GROUTING**

   A. Grout all regroutable hoses after final tunnel lining has obtained the required 28-day strength and after contact grouting has been performed.

   B. Determine injection pressure by means of on-site demonstration; do not exceed structural capacity of the structure.

   C. Clean hoses and pipes after grouting and repeat grouting operation if leak persists.

3.05 **REPAIR/RESTORATION**

   A. **LEAK REMEDIATION**
      1. Observe structure interior and control and grouting pipes by regular inspection for water leakage until the final contract completion date.
      2. If structure arch, invert, joints, or control and grouting pipes indicate dripping or seeping water perform remedial measures consisting of:
a. Grout first through regroutable hoses in the water barriers (if they exist) and then through control and grouting pipes using suitable remedial grout within the section that indicates the leak.

b. Determine injection pressure by means of an on-site demonstration; do not exceed structural capacity of the structure.

c. Clean hoses and pipes after grouting and repeat grouting operation if leak persists.

3. Do not penetrate or puncture membrane except for permanent purposes using proven water tightness techniques to be approved by the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

This Section includes specifications for fire-rated steel doors and frames, and accessories for the cross passage doors in Contract N120.

A. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 08 71 00, Door Hardware.
2. Section 09 90 00, Painting and Coating.

1.02 REFERENCES

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

1. American National Standards Institute (ANSI)
   b. ANSI/SDI A250.8 - Recommended Specifications for Standard Steel Doors and Frames.
   c. ANSI/SDI A250.10 - Test Procedure and Acceptance Criteria for Prime Painted Steel Surfaces for Steel Doors and Frames.

   a. ASTM A 653/A 653M - 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.

4. National Association of Architectural Metal Manufacturers (NAAMM)
   a. NAAMM HMMMA 840 - Guide Specifications for Installation and Storage of Hollow Metal Doors and Frames.
5. National Fire Protection Association (NFPA)

6. Underwriters Laboratories Incorporated (UL)
   a. UL 10C – Standard for Positive Pressure Fire Tests on Door Assemblies.
   b. UL 1784 - Standard for Air Leakage Tests of Door Assemblies.

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. 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.

C. Shop Drawings: Details of each opening, showing elevations, glazing, frame profiles, and identifying location of different finishes, if any.

D. Samples: Submit two samples of metal, 2 by 2 inches in size showing factory finishes, colors, and surface texture.

E. Installation Instructions: Manufacturer's published instructions, including any 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 three years documented experience.

B. 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. Protect with resilient packaging; avoid humidity build-up under coverings; prevent corrosion.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Steel Doors and Frames:
   1. Ceco Door Products.
   2. Steelcraft.
   3. Members of the Steel Door Institute and of the National Association of Architectural Metal Manufacturers, subject to compliance with the specified requirements.
   4. Substitutions: See Section 01 25 00 - Substitution Procedures.
2.02 MATERIALS

A. Doors and Frames

1. Requirements for All Doors and Frames:
   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. Hardware Preparation: In accordance with DHI A115 Series, with reinforcement welded in place, in addition to other requirements specified in door grade standard.
   g. Finish: Factory primed, for field painting.

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 must comply with the requirements specified for exterior doors and for sound-rated doors; where two requirements conflict, comply with the most stringent.

3. Door and frame shall withstand static windloads of 50 psf positive and negative when tested in accord with ASTM E330.

B. Steel Doors

1. Doors, Fire Rated:
   a. Grade: ANSI/SDI 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.
   c. Fire Rating: As indicated on Door and Frame Schedule, tested in accordance with UL 10C.
      1) Provide units listed and labeled by UL.
      2) Attach fire rating label to each fire rated unit.

C. Steel Frames

1. General:
   a. Comply with the requirements of grade specified for corresponding door.
      1) ANSI/SDI 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 or to be grouted.
d. Frames Wider than 48 Inches: Reinforce with steel channel fitted tightly into frame head, flush with top.

2. Door Frames: Face welded, seamless with joints filled.
   a. Galvanizing: All components hot-dipped zinc-iron alloy-coated (galvannealed) in accordance with ASTM A 653/A 653M, with manufacturer's standard coating thickness.
   b. Weather-stripping: See Section 08 71 00, Door Hardware.
   c. Finish: Factory primed, for field finishing.
   d. Fire Rating: Same as door, labeled.

D. Accessory Materials
   1. Grout for Frames: Portland cement grout of maximum 4-inch slump for hand troweling; thinner pumpable grout is prohibited.
   2. 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.
   3. Temporary Frame Spreaders: Provide for all factory- or shop-assembled frames.

E. Finish Materials
   1. Primer: Rust-inhibiting, complying with ANSI/SDI A250.10.
   2. 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 to be installed in masonry or to be grouted, with bituminous coating, prior to installation.
   B. Coat inside of grouted 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. Grouting Door Frames:
   1. Concrete Walls: Solidly fill space between frames and concrete with grout. Take precautions, including bracing frames, to ensure that frames are not deformed or damaged by grout forces.

E. Coordinate installation of all hardware.

F. Coordinate installation of all electrical connections to electrical hardware items.

G. Touch up damaged factory finishes.

3.04 CONSTRUCTION

A. Erection Tolerances
   1. Clearances between Door and Frame: As specified in ANSI/SDI A250.8.
   2. Maximum Diagonal Distortion: 1/16 in 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.

B. Refer to Section 08 71 00, Door Hardware.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for all hardware items for cross passage doors in Contract N120 as indicated, including fasteners and miscellaneous materials.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 01 78 23, Operation and Maintenance Data
   2. Section 08 11 13, Hollow Metal Doors and Frames

C. Where listed below, Cylinders will be furnished under this Section for material provided under other Sections.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. National Fire Protection Agency (NFPA)
      a. NFPA 80 Standard for Fire Doors and Windows

   2. American National Standards Institute (ANSI)
      a. ANSI 156.18 Materials and Finishes


1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications

C. Catalogue cuts for each item of hardware

D. Finish Hardware Schedule:
   1. Six copies of the completely detailed Hardware Schedule.
   2. List for each door opening separately, using a vertical format in accordance with the sample hardware set below:
**Door No. CP22-N**

<table>
<thead>
<tr>
<th>Description</th>
<th>Model/Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>HW1  One single door CP22-N Northbound tunnel to Cross passage 22 LHR 90 deg</td>
<td></td>
</tr>
<tr>
<td>3 feet x 7 feet x 1-3/4 inches W x HM</td>
<td></td>
</tr>
<tr>
<td>3 ea. Butts</td>
<td>CB1900 US26D 4-1/2 x 4-1/2</td>
</tr>
<tr>
<td>1 ea. Lockset</td>
<td>ML2051 LWA 630 SA114 M17</td>
</tr>
<tr>
<td>1 ea. Closer</td>
<td>DC2200 689 M54 M72 M74</td>
</tr>
<tr>
<td>1 ea. Kickplate</td>
<td>K0050 10 x 34 630</td>
</tr>
<tr>
<td>1 ea. Wall stop</td>
<td>WC9X 626</td>
</tr>
<tr>
<td>3 ea. Silencers</td>
<td>64</td>
</tr>
</tbody>
</table>

**E.** Special Tools: Two sets of all special tools required for maintenance and installation.

**F.** Operations and Maintenance Data: Maintenance manuals in accordance with Section 01 78 23, Operation and Maintenance Data. Include:

1. As-built Hardware Schedule
2. Catalog cuts
3. Template lists with template information.
4. Warranty Certificates

**G.** Parts data for exit devices, locksets & closers, and catalog cuts of all electrical hardware, including manufacturer’s name.

**1.04 QUALITY ASSURANCE**

**A.** Hardware Supplier Qualifications

1. Distributor shall have 5 years minimum experience supplying hardware for projects similar in type and scope.
2. Employ Architectural Hardware Consultants and licensed locksmiths who can be made available at all reasonable times during the course of hardware installation to meet with the Resident Engineer and Contractor for hardware or keying consultation.

**B.** Door hardware on fire rated openings: NFPA 80.

**C.** Substitutions: Section 01 25 00, Substitution Procedures.

**1.05 DELIVERY, STORAGE, AND HANDLING**

**A.** Tag each item or package to clearly identify the item and its intended location.

**B.** Package in containers clearly marked with hardware set number.

**C.** Inventory hardware jointly with the Contractor’s installation staff and the supplier’s representative until both the Contractor and the Contractor’s hardware supplier’s representative are satisfied that the count is correct.

**D.** Check, sort, and store hardware in a dry, lockable storage space.
1.06 WARRANTY

A. The finish hardware shall carry a limited warranty against defects in workmanship and operation for a period of one year from date of Substantial Completion. Door closers shall have a 10 year limited warranty.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Provide products listed in the Hardware Schedule in sufficient quantities to complete the job requirements. Items by alternate manufacturers are subject to review and acceptance by the Resident Engineer to ensure that they meet the specified requirements. Make requests for substitution in accordance with Section 01 25 00, Substitution Procedures.

B. Acceptable Manufacturers

1. Butts & Hinges: Bommer
2. Exit Devices: Von Duprin
3. Surface Closers: LCN
4. Flat goods & trim: Trimco
5. Thresholds & Gasket: Pemko
6. Electrified Hardware: GE/Sentrol

C. Furnish any Item listed in the Hardware Schedule but not listed in this Section as shown in the Hardware Schedule unless otherwise approved by the Resident Engineer in accordance with Section 01 33 00, Submittal Procedures.

2.02 FINISHES

A. Finish hardware materials as follows, unless noted otherwise in the Hardware Schedule:

1. Butts: 630
2. Locksets: 626
3. Closers: Alum
4. Exit Devices: 630
5. Thresholds: Aluminum
6. Misc. Items: 626

B. The designations used for the hardware finishes are those listed in ANSI/BHMA A156.18.

2.03 BUTTS

A. Type: As scheduled

B. Size: 3 feet wide and narrower - 4-1/2 inches by 4-1/2 inches. 3 feet 1 inch wide and over - 5 inches by 4-1/2 inches. Provide wide throw hinges where required due to trim applications or other conditions.
C. Quantity: Three each up to and including 90 inches in height. Add one additional hinge for every additional 30 inches or fraction thereof. Provide Dutch doors with a minimum of two pair of hinges. For unusual size or weight doors, furnish type, size, and quantity recommended by manufacturer.

2.04 DOOR CLOSERS, SURFACE

A. Furnish drop plates or other mounting plates where required. Provide closer of proper size and mounting style for each opening.

B. Furnish sex nuts and bolts for all doors.

C. Provide as specified in hardware groups.

2.05 GASKET AND THRESHOLD

A. Types as specified in hardware groups.

B. Provide material of proper size and configuration for the specified opening.

2.06 PRESSURE RESISTANCE

A. Hinges and locksets shall withstand static wind loads of 50 psf positive and negative when tested in accordance with ASTM E330.

PART 3 - EXECUTION

3.01 PREPARATION

A. Hardware Conference

1. After receiving approved Hardware Schedule, arrange a meeting to be attended by the hardware supplier, Contractor, and Resident Engineer. Review and confirm all lockset function and electrical operations and conditions affecting the access controls and other electronic operators and controls. Obtain from the hardware supplier six complete copies of the keying schedule and explanations of the operation of the electronic hardware for distribution to the appropriate parties. Include in this document riser diagrams and point to point wiring diagrams to facilitate the correct installation of the material.

B. Templates:

1. After receiving approved Hardware Schedule, supply templates or physical hardware to fabricator of factory prepared doors, frames, and other work affected.

3.02 INSTALLATION

A. Perform installation by skilled craftspersons, experienced in the installation of commercial builders hardware, and in accordance with the approved shop drawings of Section 08 11 13, Hollow Metal Doors and Frames.

B. Install according to manufacturer's standard locations except as otherwise directed by the Resident Engineer. Where cutting and fitting are required to install hardware onto or into surfaces that are later to be finished, coordinate removal, storage and reinstallation with finishing work. Do not install surface mounted items until finishes have been completed on the substrates involved.
C. Set units level, plumb, and true to line and location. Adjust and reinforce the attachment substrate as necessary for proper installation and operation.

D. Drill and countersink units that are not factory prepared for anchorage fasteners. Space fasteners and anchors in accordance with industry standards.

E. Weather-stripping and Seals: Comply with manufacturer’s instructions and recommendations to the extent installation requirements are not otherwise indicated.

3.03 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. Return to the installation during the week prior to Substantial Completion and make a final check and adjustment of all hardware items with the Resident Engineer. Clean and adjust operating items as necessary to restore proper function and finish of hardware and doors. Clean all adjacent surfaces soiled by hardware operation.

3.04 HARDWARE SCHEDULE

A. Refer to door schedule and related information concerning the following hardware groups. Quantities indicated in any instance are for supplier convenience only and are not guaranteed. NOTE: Electrical items are indicated by **//** for coordination with electrical subcontractor. Example: 1 each Magnetic holder FM998 **//**

B. Hardware Schedule by Group:

<table>
<thead>
<tr>
<th>HW1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hinges</td>
<td>BB5004</td>
</tr>
<tr>
<td>1 ea exit device</td>
<td>9875L-F x 996L-BE</td>
</tr>
<tr>
<td>1 ea. Closer</td>
<td>4041 R W/PA, Hinge side mount</td>
</tr>
<tr>
<td>1 ea. Floor Stop</td>
<td>1211</td>
</tr>
<tr>
<td>1 set Smoke Seal</td>
<td>S88GR</td>
</tr>
<tr>
<td>Threshold</td>
<td>1715A</td>
</tr>
<tr>
<td>Door Bottom</td>
<td>29324CNB</td>
</tr>
<tr>
<td>1 set Door Position Switch</td>
<td>2507A-L <strong>//</strong></td>
</tr>
</tbody>
</table>

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for surface preparation, painting, and finishing of hollow metal doors and frames. Surface preparation, priming, and finish coats specified in this Section are in addition to shop-priming and surface treatment specified under other Sections.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. Code of Federal Regulation
      b. ASTM D16 Standard Terminology for Paint, Related Coatings, Materials, and Applications
      c. ASTM D1400 Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base
      d. ASTM D3359 Standard Test Methods for Measuring Adhesion by Tape Test

1.03 DEFINITIONS
A. Refer to ASTM D16 for interpretation of terms used in this section.

1.04 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Provide data on all finishing products, including VOC content.
1. Manufacturer’s technical information including label analysis and instructions for handling, storage, and application of each material proposed for use.

2. List 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. Samples: Submit four each color samples, 8 x 10 inch in size illustrating range of colors and textures available for each surface finishing product scheduled. Submit on representative substrate material.

D. Certifications:
   1. By manufacturer that all paints and coatings comply with VOC limits specified.
   2. By manufacturer that all paints and coatings do not contain any of the prohibited chemicals specified; GreenSeal GS-11 certification is not required but if provided shall constitute acceptable certification.

E. Manufacturer's Instructions: Indicate special surface preparation procedures.

F. Maintenance Data: Submit data on cleaning, touch-up, and repair of painted and coated surfaces.

1.05 QUALITY ASSURANCE

A. Manufacturer Qualifications: Company specializing in manufacturing the Products specified in this section with minimum ten years documented experience.

B. Applicator Qualifications: Company specializing in performing the work of this section, employing experienced applicators who have completed painting system applications similar in material and extent to those indicated that have resulted in a construction record of successful in-service performance with minimum five years experience.

1.06 REGULATORY REQUIREMENTS

A. Conform to applicable code for flame and smoke rating requirements for all products and finishes.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Deliver products to site in sealed and labeled containers; inspect to verify acceptability.

B. Container Label: Include manufacturer's name, type of paint, brand name, lot number, brand code, coverage, surface preparation, drying time, cleanup requirements, color designation, and instructions for mixing and reducing. Report any containers seen on site without Container Labels immediately to the Resident Engineer.

C. Paint Materials: Store at minimum ambient temperature of 45 degrees F and a maximum of 90 degrees F, in ventilated area, and as required by manufacturer's instructions.

1.08 ENVIRONMENTAL REQUIREMENTS

A. Do not apply materials when surface and ambient temperatures are outside the temperature ranges required by the paint product manufacturer.

B. Do not apply coatings when relative humidity is outside the humidity ranges required by the paint product manufacturer.
1. Painting may continue when environmental conditions are outside of manufacturer’s ranges if surfaces and areas to be painted are enclosed and heated within temperature limits specified by the manufacturer during application and drying periods.

C. Application Temperatures for all Paints:  50 degrees F minimum, 90 degrees maximum, unless required otherwise by manufacturer’s instructions.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Paints not otherwise specified: "First Quality" commercial products from Manufacturers listed in the ASM, subject to Resident Engineer’s approval.

4. Substitutions: See Section 01 25 00, Substitution Procedures.

B. Special Coating Systems for Metals:

2. Substitutions: See Section 01 25 00, Substitution Procedures.

2.02 PAINTS AND COATINGS - GENERAL

A. 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.

B. Material Quality: Provide the manufacturer’s best-quality trade sale paint material of the various coating types specified. Paint material containers not displaying manufacturer’s product identification will not be acceptable.

1. Proprietary Names: Use of manufacturer’s proprietary product names to designate colors or materials is not intended to imply that products named are required to be used to the exclusion of equivalent products of other manufacturers. Furnish the manufacturer’s material data and certificates of performance for proposed substitutions.

C. Colors: Provide custom color of the finished paint systems to match the Architect’s selection.

D. Paints and Coatings: Ready-mixed, except field-catalyzed coatings. Prepare pigments:

1. To a soft paste consistency, capable of being readily and uniformly dispersed to a homogeneous coating.
2. For good flow and brushing properties.
3. Capable of drying or curing free of streaks or sags.
E. Volatile Organic Compound (VOC) Content:

1. Provide coatings that comply with the most stringent requirements specified in the following:

2. Determination of VOC Content: Testing and calculation in accordance with 40 CFR 59, Subpart D (EPA Method 24), exclusive of colorants added to a tint base and water added at project site; or other method acceptable to authorities having jurisdiction.

F. Chemical Content: The following compounds are prohibited:

1. Aromatic Compounds: In excess of 1.0 percent by weight of total aromatic compounds (hydrocarbon compounds containing one or more benzene rings).

2. Acrolein, acrylonitrile, antimony, benzene, butyl benzyl phthalate, cadmium, di (2-ethylhexyl) phthalate, di-n-butyl phthalate, di-n-octyl phthalate, 1,2-dichlorobenzene, diethyl phthalate, dimethyl phthalate, ethylbenzene, formaldehyde, hexavalent chromium, isophorone, lead, mercury, methyl ethyl ketone, methyl isobutyl ketone, methylene chloride, naphthalene, toluene (methylbenzene), 1,1,1-trichloroethane, vinyl chloride.

2.03 PAINT SYSTEMS

A. Special Coating System for Ferrous Metals:

1. First Coat: Sherwin Williams Recoatable Epoxy Primer. 4.0 – 6.0 mils dft.

2. Finish Coats: Sherwin Williams Corothane II. 2.0 – 4.0 mils dft.

2.04 ACCESSORY MATERIALS

A. Accessory Materials: VOC-compliant linseed oil, shellac, turpentine, paint thinners and other materials not specifically indicated but required to achieve the finishes specified; commercial quality.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that surfaces are ready to receive Work as instructed by the product manufacturer.

B. Examine surfaces scheduled to be finished prior to commencement of work. Report any condition that may potentially affect proper application.

C. Test shop-applied primer for compatibility with subsequent cover materials. Surfaces receiving paint must be thoroughly dry before paint is applied.

1. Do not begin to apply paint until unsatisfactory conditions have been corrected.

2. Start of painting shall as the Applicator’s acceptance of surfaces and conditions within a particular area
D. Coordination of Work: Review other Sections in which primers are provided to ensure compatibility of the total system for various substrates. On request, furnish information on characteristics of finish materials to ensure use of compatible primers.

1. Notify the Resident Engineer about anticipated problems using the materials specified over substrates primed by others.

3.02 PREPARATION

A. Surface Appurtenances: Remove or mask electrical plates, hardware, light fixture trim, escutcheons, and fittings prior to preparing surfaces or finishing. Remove items already installed that are not to be painted, or provide surface-applied protection prior to surface preparation and painting. Remove these items, if necessary, to completely paint the items and adjacent surfaces. Following completion of painting operations in each space or area, have items reinstalled by workers skilled in the trades involved.

B. Cleaning: Before applying paint or other surface treatments, clean the substrates of substances that could impair the bond of the various coatings. Remove oil and grease prior to cleaning. Schedule cleaning and painting so dust and other contaminants from the cleaning process will not fall on wet, newly painted surfaces.

C. Surfaces: Correct defects and clean surfaces which affect work of this section, according to manufacturer's instructions. Remove or repair existing coatings that exhibit surface defects.

1. Provide barrier coats over incompatible primers or remove and reprime. Notify Architect in writing about anticipated problems using the specified finish-coat material with substrates primed by others.

D. Marks: Seal with shellac those which may bleed through surface finishes.

E. Impervious Surfaces: Remove mildew by scrubbing with solution of tetra-sodium phosphate and bleach. Rinse with clean water and allow surface to dry.

F. Shop-Primed Steel Surfaces to be Finish Painted: Sand and scrape to remove loose primer and rust. Feather edges to make touch-up patches inconspicuous. Clean surfaces with solvent. Prime bare steel surfaces. Re-prime entire shop-primed item.

G. Metal Doors: Prime metal door top and bottom edge surfaces.

H. Materials Preparation: Carefully mix and prepare paint materials according to manufacturer's directions.

1. Maintain containers used in mixing and applying paint in a clean condition, free of foreign materials and residue.

2. Stir material before application to produce a mixture of uniform density; stir as required during application. Do not stir surface film into material. Remove film and, if necessary, strain material before using.

3. Use only thinners approved by the paint manufacturer and only within recommended limits.

3.03 APPLICATION

A. Paint all exposed door and frame surfaces whether or not colors are designated in schedules, except where a surface or material is specifically indicated not to be painted or is to remain natural. Where an item or surface is not specifically mentioned, paint the
same as similar adjacent materials or surfaces. If color or finish is not designated, the Resident Engineer will select from specified colors or finishes for this project.

1. Finished metal surfaces not to be painted include:
   a. Factory-finished aluminum.
   b. Anodized aluminum.
   c. Stainless steel.
   d. Chromium plate.
   e. Copper.
   f. Bronze.
   g. Brass.

2. Do not paint moving parts of operating equipment.

3. Labels: Do not paint over Underwriters Laboratories, Factory Mutual or other code-required labels or equipment name, identification, performance rating, or nomenclature plates.

B. Apply products in accordance with manufacturer's instructions. Use applicators and techniques best suited for substrate and type of material being applied.

C. Do not apply finishes to surfaces that are not dry. Do not paint over dirt, rust, scale, grease, moisture, scuffed surfaces, or conditions detrimental to formation of a durable paint film. Allow applied coats to dry before next coat is applied.

D. Apply each coat to uniform appearance. Apply each coat of paint slightly darker than preceding coat unless otherwise approved.

1. Paint colors, surface treatments, and finishes are indicated in the schedules.

2. Provide finish coats that are compatible with primers used.

3. The number of coats and the film thickness required are the same regardless of the application method. Do not apply succeeding coats until the previous coat has cured as recommended by the manufacturer. Sand between each application entire surface to produce a smooth even surface according to the manufacturer's directions.

4. Apply additional coats if undercoats, stains, or other conditions show through final coat of paint until paint film is of uniform finish, color, and appearance. Give special attention to ensure that surfaces, including edges, corners, crevices, welds, and exposed fasteners, receive a dry film thickness equivalent to that of flat surfaces.

5. The term exposed surfaces includes areas visible when permanent or built-in fixtures, convextor covers, covers for finned tube radiation, grilles, and similar components are in place. Extend coatings in these areas, as required, to maintain the system integrity and provide desired protection.

6. Finish doors on tops, bottoms, and side edges same as exterior faces.
E. Prime Coats: Before applying finish coats, apply a prime coat of material, as recommended by the manufacturer, to material that is required to be painted or finished.

F. Pigmented (Opaque) Finishes: Completely cover to provide a smooth, opaque surface of uniform finish, color, appearance, and coverage. Cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness, or other surface imperfections will not be acceptable.

G. Completed Work: Match approved samples for color, texture, and coverage. Remove, refinish, or repaint work not complying with specified requirements.

H. Scheduling Painting: Apply first coat to surfaces that have been cleaned, pretreated, or otherwise prepared for painting as soon as practicable after preparation and before subsequent surface deterioration.

1. Allow sufficient time between successive coats to permit proper drying. Do not recoat until paint has dried to where it feels firm, does not deform or feel sticky under moderate thumb pressure, and where application of another coat of paint does not cause the undercoat to lift or lose adhesion.

I. Minimum Coating Thickness: Apply materials no thinner than the manufacturer’s recommended spreading rate. Provide the total dry film thickness of the entire system as scheduled.

J. Vacuum clean surfaces of loose particles. Use tack cloth to remove dust and particles just prior to applying next coat.

3.04 FIELD QUALITY CONTROL

A. See Section 01 45 00, Quality Control, for general requirements for field inspection.

B. Sound Transit may engage the services of an independent testing agency to sample the paint material being used. Samples of material delivered to the Project will be taken, identified, sealed, and certified in the presence of the Contractor.

1. If test results show material being used does not comply with specified requirements, the Contractor may be directed to stop painting, remove non-complying paint, pay for testing, repaint surfaces coated with rejected paint, and remove rejected paint from previously painted surfaces if, upon repainting with specified paint, the two coatings are incompatible.

C. Sound Transit may engage the services of an independent testing agency to test the applied coatings for adhesion and film thickness using, but not limited to, the following tests. Repair areas of coating that have been damaged due to testing.


2. ASTM D1400 Standard Test Method for Nondestructive Measurement of Dry Film Thickness of Nonconductive Coatings Applied to a Nonferrous Metal Base

3. ASTM D3359 Standard Test Methods for Measuring Adhesion by Tape Test

3.05 CLEANING

A. Collect waste material which may constitute a fire hazard, place in closed metal containers, and remove daily from site.
B. At the end of each work day, remove empty cans, rags, rubbish, and other discarded paint materials from the site.

C. Remove spattered paint by washing and scraping. Be careful not to scratch or damage adjacent finished surfaces.

3.06 PROTECTION

A. Protect work of other trades, whether being painted or not, against damage by painting. Correct damage by cleaning, repairing or replacing, and repainting, as acceptable to the Resident Engineer.

B. Provide “Wet Paint” signs to protect newly painted finishes. Remove temporary protective wrappings provided by others to protect their work after completing painting operations.

C. At completion of construction activities of other trades, touch up and restore damaged or defaced painted surfaces.

3.07 SCHEDULE - COLORS

A. Hollow Metal Doors and Frames: Match Sound Transit standard “Charcoal Gray”

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing traffic signs, sign removal, sign relocation, and refacing existing signs as indicated.

1.02 REFERENCES

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

1. City of Seattle (COS)
   a. Standard Specifications for Road, Bridge, and Municipal Construction, including provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   b. Standard Plans for Municipal Construction

2. Washington State Department of Transportation (WSDOT)
   a. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   b. Standard Plans for Road, Bridge, and Municipal Construction
   c. Sign Fabrication Manual, M55-05


1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Manufacturers’ product data for sign materials.

PART 2 - PRODUCTS

2.01 MATERIALS

A. For roadway signage on Sound Transit owned streets, roadways, and parking lots, use materials, including posts, as indicated on the Contract Drawings and conform to the applicable provisions of WSDOT 8-21, unless specified otherwise.

B. For roadway signage on streets, roadways, and parking areas that will be owned or maintained by WSDOT, City of Seattle, or University of Washington, use materials that conform to the standard drawings and specifications of the respective owner.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For roadway signage on Sound Transit owned streets, roadways, and parking lots, perform work described in this Section in accordance with the applicable provisions of WSDOT 8-21, unless specified otherwise.

B. For roadway signage on streets, roadways and parking areas that will be owned or maintained by WSDOT, City of Seattle, or University of Washington, perform work described in this Section in accordance with the standard drawings and specifications of the respective owner.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for piping materials, mechanical sleeve seals, sleeves, escutcheons, fire-stopping sealant, and common installation instructions for Division 21 piping systems.

B. This Section also includes fire extinguishers for each cross passage.

C. Related Sections: The work of the following Sections is related to the work of this Section.

1. Section 01 78 23, Operation and Maintenance Data
2. Section 03 62 00, Grout
3. Section 05 50 00, Metal Fabrications.
4. Section 21 12 00, Fire Suppression Standpipes

1.02 REFERENCES

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

1. American Society of Mechanical Engineers
   a. ASME BPVC Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications
   b. ASME B31.1, Power Piping Code
   c. ASME B1.20.1 Pipe Threads, General Purpose
   d. ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges

   a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless

3. American Welding Society (AWS)
   a. AWS D1.1 Structural Welding Code-Steel
4. City of Seattle
   a. Seattle Fire Code (International Fire Code with Seattle Amendments)

5. Factory Mutual Global
   a. Approval Guide (FM Approved)

   a. NFPA 14 Standard for the Installation of Standpipe and Hose Systems
   b. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail
   c. NFPA 10 Standard for Portable Fire Extinguishers

7. Underwriters Laboratory Listings (UL Listed)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each type of product indicated. Include rating and classification, material descriptions, dimensions of individual components and profiles, and finishes for mounting brackets. Provide product data for fire extinguishers.
C. Operation and Maintenance Manuals: Submit operation and maintenance instructions and data for equipment provided under this Division, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data.
D. Welding certificates.

1.04 QUALITY ASSURANCE
A. Steel Support Welding: Qualify processes and operators according to AWS D1.1.
B. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.
C. NFPA Compliance: Fabricate and label fire extinguishers to comply with NFPA 10, "Portable Fire Extinguishers."
D. Fire Extinguishers: Listed and labeled for type, rating, and classification by an independent testing agency acceptable to authorities having jurisdiction.
E. All equipment and component assemblies furnished and installed on the fire suppression system shall be UL listed and FM approved for its specific use.

1.05 WARRANTY
A. Fire Extinguisher Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace fire extinguishers that fails in materials or workmanship within specified warranty period.
1. Failures include, but are not limited to, the following:
   a. Failure of hydrostatic test according to NFPA 10.
   b. Faulty operation of valves or release levers.

2. Warranty Period: Six years from date of Final Acceptance.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe, Tube and Fittings
   1. Joining Methods: See specific Division 21 piping Sections.
   2. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

B. Joining Material
   1. Pipe-Flange Gasket Materials: ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.

C. Mechanical Sleeve Seals: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.
   1. Sealing Elements: Ethylene Propylene Diene Monomer (EPDM) interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.
   2. Pressure Plates: Stainless steel, include two for each sealing element.
   3. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

D. Sleeves
   1. Steel Sheet-Metal: For pipe 6 inch nominal size and larger, 8 gauge galvanized sheet metal, round tube closed with welded longitudinal joint, constructed to inside diameter noted on drawings.
   2. Steel Pipe: For pipe smaller than nominal 6-inch size, ASTM A53, Type E, Grade B, Schedule 40, galvanized, plain ends.

E. Escutcheons: Manufactured wall and ceiling escutcheons and floor plates, with an inner diameter (ID) to closely fit around pipe or tube and an outer diameter (OD) that completely covers opening.
   1. One-Piece, Deep- Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.
   2. One-Piece, Cast-Brass Type: With set screw and polished chrome-plated finish.
3. **Split-Casting, Cast-Brass Type:** With concealed hinge and set screw and polished chrome-plated finish.

**F. Grout:** Refer to Section 03 62 00 for grout specification.

**G. Fire-Stopping Sealant:** Material shall be asbestos-free and capable of maintaining an effective barrier against flame and gases. Provide joint sealants with fire resistance ratings indicated, as determined in accordance with ASTM E 119, but not less than that equaling or exceeding the fire-resistance rating of the assembly in which firestop material is installed. The fire resistance rating for penetrations into the tunnel cross passages shall be 2 hours. Provide products with flame-spread values of less than 25 and smoke-developed values of less than 50, as determined in accordance with ASTM E 84.

1. Prepackaged, dry mixes consisting of a blend of inorganic binders, hydraulic cement, fillers, and lightweight aggregate formulated for mixing with water at Project site to form a non-shrinking, homogeneous mortar.

2. **Silicone Sealants:** Moisture-curing, single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below:

   **Grade:** Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces and nonsag formulation for openings in vertical surfaces requiring a nonslumping, gunnable sealant, unless indicated firestop system limits use to nonsag grade for both opening conditions.

**H. Steel Slotted Support Systems:** Comply with MFMA-4, factory-fabricated component for field assembly.

1. **Metallic Coatings:** Hot-dip galvanized after fabrication and applied according to MFMA-4.

2. **Channel Dimensions:** Selected for load supported.

**I. Attachments:**

1. **Concrete and Masonry Anchor Bolts and Studs:** Attachments with pull-out and shear capacities appropriate for supported loads and building materials where used, as follows:

   a. **Tunnel Anchor Bolts:** Anchor bolts in the tunnel shall be stainless steel mechanical anchor type or epoxy anchor bolts. Both types shall be rated for dynamic loading. Anchor bolt sizes and embedment lengths indicated on the drawings are for mechanical type anchors. Epoxy anchor bolts shall provide equivalent or greater strength at an ambient temperature of 215 deg F.

   b. **Mechanical Anchor Bolts:** Mechanical anchor bolts shall be stainless steel hex head finished bolt with a longitudinally tapered threaded end and a spring loaded multi-part conforming threaded expander nut. Anchor shall meet Fed. Spec. A-A 1923A for description of shield expansion (lag, machine and externally threaded wedge bolt anchors), Type 4. Expansion anchor elements shall be AISI 304 or 316 stainless steel. Anchors shall be Hilti Kwik Bolt TZ Expansion Anchor or approved equal and compliant with the 2006 International Building Code.

   c. **Epoxy Anchor Bolts:** Epoxy anchor bolts shall be stainless steel all-thread, encapsulated epoxy type with embedment length and drilled hole diameter per the manufacturer’s recommendations. Polyester and vinyl
resin is not acceptable. Anchors shall be Hilti HAS-E-SS or approved equal. Epoxy compound shall be Hilti RE-500-SD or approved equal and compliant with the 2006 International Building Code.

d. Load ratings shall be equal or better than those listed for the specified Hilti anchor and the anchor size and minimum embedment shown on the drawings.

2.02 FIRE EXTINGUISHERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product by one of the following:

1. Amerex Corporation.
2. Ansul Incorporated; Tyco International Ltd.
5. Kidde Residential and Commercial Division; Subsidiary of Kidde plc.
6. Potter Roemer LLC.

B. Valves: Manufacturer's standard.

C. Handles and Levers: Manufacturer's standard.

D. Instruction Labels: Include pictorial marking system complying with NFPA 10, Appendix B.

E. Multipurpose Dry-Chemical Type in Steel Container UL-rated 4-A:40-B:C, 8.5-lb nominal capacity, with monoammonium phosphate-based dry chemical in enameled-steel container.

F. Mounting Bracket: Manufacturer's standard galvanized steel, designed to secure fire extinguisher to wall or structure, of sizes required for types and capacities of fire extinguishers indicated, with plated or red baked-enamel finish.

G. Identification: Lettering complying with authorities having jurisdiction for letter style, size, spacing, and location. Location shall be acceptable to Resident Engineer.

1. Identify bracket-mounted fire extinguishers with the words "FIRE EXTINGUISHER" in red letter decals applied to mounting surface.

PART 3 - EXECUTION

3.01 PREPARATION

A. Obtain permits under Seattle Fire Department and as required by Seattle Fire Code for use of flammable liquids, hazardous materials, compressed gases, cutting and welding equipment.
B. Examine fire extinguishers for proper charging and tagging.
   1. Remove and replace damaged, defective, or undercharged fire extinguishers.

3.02 ERECTION
A. Metal Supports and Anchorages
   1. Refer to Section 05 50 00, Metal Fabrications, for structural steel.
   2. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor fire-suppression materials and equipment.
   3. Field Welding: Comply with AWS D1.1.

3.03 INSTALLATION
A. Piping Systems
   1. Install piping according to the following requirements.
   2. The Contract Drawings indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion and contraction, and other design considerations. Install piping as indicated unless deviations to layout are approved by the Resident Engineer.
   3. Install piping indicated to be exposed at right angles or parallel to structure walls unless otherwise indicated on the Contract Drawings. Diagonal runs are prohibited unless specifically indicated.
   4. Install piping to permit valve servicing, and at indicated slopes. Piping shall be free of sags and bends. Install fittings for changes in direction and branch connections. Install escutcheons for penetrations of walls and floors.
   5. Install sleeves, type as indicated on drawing, for pipes passing through concrete and masonry walls, and concrete floor slabs.
      a. All interior through-penetrations shall be sleeved and protected using fire-stopping sealant in accordance with manufacturer’s instructions and to provide a through-penetration flame rating of 3 hours in accordance with UL 1479.
   6. Verify final equipment locations for roughing-in.

B. Install fire extinguishers and mounting brackets in each cross passage as directed by the Resident Engineer and in compliance with requirements of authorities having jurisdiction.
   1. Mounting Brackets: 54 inches above finished floor to top of fire extinguisher.

3.04 GROUTING
1. Mix and install grout for fire-suppression equipment and piping support base bearing surfaces, and other equipment base plates, and anchors.
2. Clean surfaces that will come into contact with grout.
3. Provide forms as required for placement of grout.
4. Avoid air entrapment during placement of grout.
5. Grout Placement:
   a. Completely fill equipment bases
   b. On concrete bases to provide smooth bearing surface for equipment
   c. Around anchors
6. Cure placed grout.

3.05 CONSTRUCTION

A. Piping Joints: According to the following requirements
   1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
   2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
   3. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. 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:
      a. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
      b. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.
   5. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

3.06 FIELD QUALITY CONTROL

A. Fire Extinguishers: Refer to 01 77 00 Closeout procedures.

END OF SECTION
SECTION 21 05 33
HEAT TRACING FOR FIRE SUPPRESSION PIPING

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes heat tracing with the following electric heating cables:
   1. Self-regulating, parallel resistance.
B. Related Sections: The work of the following Sections is related to the work of this Section
   1. Section 01 78 23, Operation and Maintenance Data.
   2. Section 01 77 00, Closeout Procedures
   3. Section 21 05 00, Common Work Results for Fire Suppression
   4. Section 21 07 00, Fire Suppression Systems Insulation.
   5. Section 26 05 25, Wire and Cable.
   6. Section 26 05 26, Grounding and Bonding for Electrical Systems.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle (COS)
      a. Seattle Fire Code (International Fire Code with Seattle Amendments)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories for each type of product indicated.
   1. Schedule heating capacity, length of cable, spacing, and electrical power requirement for each electric heating cable required.
C. Shop Drawings: For electric heating cable. Include plans, sections, details, and attachments to other work.
D. Field quality-control test reports.
E. Operation and Maintenance Manuals: Section 21 05 00, Common Work Results for Fire Suppression and Section 01 78 23, Operation and Maintenance Data. In addition to these requirements include data for electric heating cables, control panel and RTD sensor cable and warranty slip.

F. Warranty: Special warranty specified in this Section.

1.04 QUALITY ASSURANCE

A. Heat Trace Cables: UL Listed for use on Fire Protection System Piping.

B. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

C. Monitoring and alarm functions shall comply with Seattle Fire Department Administrative Rule 9.03.07.

1.05 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace electric heating cable that fails in materials or workmanship within specified warranty period.

1. Warranty Period: 10 years from date of Substantial Completion.

PART 2 - PRODUCTS

2.01 SELF-REGULATING, PARALLEL-RESISTANCE HEATING CABLES

A. Basis-of-Design Product: Subject to compliance with requirements, provide Thermon FLX Self Regulating Heating Cable and Thermon GPT-3 Freeze Protection Thermostat or a comparable UL listed product by one of the following:

1. Chromalox, Inc.; Wiegard Industrial Division; Emerson Electric Company.


3. Raychem; a Division of Tyco Thermal Controls.

B. Heating Element: Pair of parallel No. 16 AWG, nickel-coated stranded copper bus wires embedded in crosslinked conductive polymer core, which varies heat output in response to temperature along its length. Terminate with waterproof, factory-assembled non-heating leads with connectors at the power end, and seal the opposite end watertight. Cable shall be capable of crossing over itself once without overheating.

C. Electrical Insulating Jacket: Flame-retardant polyolefin.

D. Cable Cover: Tinned-copper braid, and polyolefin outer jacket with UV inhibitor.

E. Maximum Operating Temperature (Power On): 150 degrees F.

F. Maximum Exposure Temperature (Power Off): 185 degrees F.

G. Maximum Operating Temperature: 300 degrees F.
H. Capacities and Characteristics:

3. Number of Parallel Cables: 1
4. Volts: 277 V.
5. Phase: 1
6. Hertz: 60 Hz.
7. Maximum Circuit Length for 0 degree F Start-up Temperature: 649 ft.

2.02 CONTROLS

A. Heater Trace Circuit Controller: Automatic electronic controller with provisions for remote temperature sensor input, internal ground fault protection, and monitoring functions for each heat trace circuit.

1. Control Range: 41 degrees F to 77 degrees F adjustable, with 2 degrees F dead band.
2. Electrical Supply: 277 V, 1 phase, 60 hertz; 2-pole contact suitable for 30 amps maximum load.
3. GFI Protection: 30, 60, 90, or 120 mA selectable with automatic reset.
4. Monitoring Functions: Power-on self-check, heater operation, GFI protection and ground leakage current tested every 24 hours, temperature sensor operation, and contactor operation.
5. Alarm Relay: Single-throw double-pole 1 amp class 2 contact.
6. Indicators: Lights mounted on enclosure for normal power, call for heat, ground fault occurrence, or a failure of the monitored functions.
7. Enclosure: NEMA 3R.

B. Remote temperature sensor: Resistance Temperature Detector (RTD) supplied for field installation on pipe for direct sensing of pipe-wall temperature at beginning and end of each heat trace circuit.

2.03 ACCESSORIES

A. Cable Installation Accessories: Pipe-mounted non-metallic heat trace power circuit connection box, fiberglass tape, heat-conductive putty, cable ties, silicone end seals and splice kits, and installation clips all furnished by manufacturer, or as recommended in writing by manufacturer.

B. Warning Tape: Continuously printed "Electrical Tracing"; vinyl, at least 3 mils thick, and with pressure-sensitive, permanent, waterproof, self-adhesive back.
1. Width for Markers on Pipes with OD, Including Insulation, 6 Inches or Larger: 1-1/2 inch minimum.

2.04 RTD EXTENSION WIRE
   A. For extending RTD signal leads; Silver-plated copper wire with Teflon or PVC insulation and jacket; two or three conductors as required by Heat Trace Circuit Controller manufacturer.

PART 3 - EXECUTION

3.01 EXAMINATION
   A. Examine surfaces and substrates to receive electric heating cables for compliance with requirements for installation tolerances and other conditions affecting performance.
      1. Ensure surfaces and pipes in contact with electric heating cables are free of burrs and sharp protrusions.
      2. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 INSTALLATION
   A. Mount heat trace circuit controllers on support assembly secured to cross passage final lining. Refer to Section 21 05 00, Common Work Results for Fire Suppression, for slotted support systems and attachments.
   B. Install electric heating cable across expansion joints according to manufacturer's written recommendations using slack cable to allow movement without damage to cable.
   C. Install electric heating cables after piping has been tested and before insulation is installed.
   D. Install electric heating cables according to IEEE 515.1.
   E. Install insulation over piping with electric cables according to Section 21 07 00, Fire Suppression Systems Insulation.
   F. Install warning tape on piping insulation where piping is equipped with electric heating cables.
   G. Set field-adjustable switches and circuit-breaker trip ranges.
   H. Protect installed heating cables, including non-heating leads, from damage.

3.03 CONNECTIONS
   A. Ground equipment according to Section 26 05 26, Grounding and Bonding for Electrical Systems.
   B. Connect wiring according to Section 26 05 25, Wire and Cable.

3.04 FIELD QUALITY CONTROL
   A. Testing: Perform tests after cable installation but before application of coverings such as insulation, wall or ceiling construction, or concrete.
1. Test cables for electrical continuity and insulation integrity before energizing.

2. Test cables to verify rating and power input. Energize and measure voltage and current simultaneously.

B. Repeat tests for continuity, insulation resistance, and input power after applying thermal insulation on pipe-mounting cables.

C. Remove and replace malfunctioning units and retest as specified above.

D. Closeout Procedures: Refer to Section 01 77 00, Closeout Procedures.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section Includes specifications for:

1. Insulation Materials:
   a. Mineral fiber.

2. Mastics.

3. Factory-applied jackets.

4. Field-applied jackets.

5. Tapes.


1.02 REFERENCES

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

1. American Society for Testing and Materials (ASTM)
   b. ASTM A240 Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
   c. ASTM B209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
   d. ASTM C795 Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel
   e. ASTM C1136 Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation

2. City of Seattle (COS):
   a. Seattle Fire Code (International Fire Code with Seattle Amendments)
1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: For each type of product indicated. Include thermal conductivity, thickness, and jackets (both factory and field applied, if any).

C. Shop Drawings:

1. Detail application of protective shields, saddles, and inserts at hangers for each type of insulation and hanger.

2. Detail attachment and covering of heat tracing inside insulation.

3. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.

4. Detail removable insulation at piping specialties and equipment connections.

5. Detail application of field-applied jackets.

D. Qualification Data: For qualified Installer

E. Material Test Reports: From a qualified testing agency acceptable to authorities having jurisdiction indicating, interpreting, and certifying test results for compliance of insulation materials, sealers, attachments, cements, and jackets, with requirements indicated. Include dates of tests and test methods employed.

F. Field quality-control reports.

1.04 QUALITY ASSURANCE

A. Installer Qualifications: Skilled mechanics who have successfully completed an apprenticeship program or another craft training program certified by the Department of Labor, Bureau of Apprenticeship and Training.

B. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products in accordance with ASTM E84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, and cement material containers, with appropriate markings of applicable testing and inspecting agency.

1. Insulation Installed In Tunnels: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Packaging: Insulation material containers shall be marked by manufacturer with appropriate ASTM standard designation, type and grade, and maximum use temperature.

1.06 COORDINATION

A. Coordinate size and location of supports, hangers, and insulation shields.

B. Coordinate clearance requirements with piping Installer for piping insulation application and equipment Installer for equipment insulation application. Before preparing piping
Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

C. Coordinate with the installation and testing of heat tracing system.

1.07 SCHEDULING

A. Schedule insulation application after pressure testing pipe systems and after installing and testing of the heat tracing. Insulation application may begin on segments that have satisfactory test results.

PART 2 - PRODUCTS

2.01 INSULATION MATERIALS

A. Products shall not contain asbestos, lead, mercury, or mercury compounds.

B. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C871.

C. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C795.

D. Mineral-Fiber, Preformed Pipe Insulation:

1. Products: Subject to compliance with requirements, provide one of the following:
   a. Johns Manville; Micro-Lok.
   b. Knauf Insulation; 1000(Pipe Insulation).
   c. Owens Corning; Fiberglas Pipe Insulation.

2.02 MASTICS

A. Materials shall be compatible with insulation materials, jackets, and substrates; comply with MIL-C-19565C, Type II.

2.03 FACTORY-APPLIED JACKETS

A. When factory-applied jackets are indicated, comply with the following:

1. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C1136, Type I.

2.04 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C921, Type I, unless otherwise indicated.

B. Metal Jacket:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Pabco-Childers Metals, Division of ITW; Metal Jacketing Systems.
b. RPR Products, Inc.; Insul-Mate.

   a. Sheet and roll stock ready for shop or field sizing.
   b. Smooth finish and minimum thickness of 0.02 inch.
   c. Moisture Barrier for Outdoor Applications: 3-mil-thick, polysurlyn heat laminated to the metal jacketing
   d. Factory-Fabricated Fitting Covers:
      1) Same material, finish, and thickness as jacket.
      2) Preformed two-piece or gore, 45- and 90-degree, short- and long-radius elbows.
      3) Tee covers.
      4) Flange and union covers.
      5) End caps.
      6) Beveled collars.
      7) Valve covers.
      8) Field fabricate fitting covers only if factory-fabricated fitting covers are not available.

2.05 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C1136.
   1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      a. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0835.
      b. Compac Corp.; 104 and 105.
      c. Ideal Tape Co., Inc., an American Biltrite Company; 428 AWF ASJ.
      d. Venture Tape; 1540 CW Plus, 1542 CW Plus, and 1542 CW Plus/SQ.
   2. Width: 3 inches.
   3. Thickness: 11.5 mils.
   5. Elongation: 2 percent.
   6. Tensile Strength: 40 lbf/inch in width.
   7. ASJ Tape Disks and Squares: Precut disks or squares of ASJ tape.
B. Aluminum-Foil Tape: Vapor-retarder tape with acrylic adhesive.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
   b. Compac Corp.; 120.
   c. Ideal Tape Co., Inc., an American Biltrite Company; 488 AWF.
   d. Venture Tape; 3520 CW.

2. Width: 2 inches.

3. Thickness: 3.7 mils.


5. Elongation: 5 percent.

6. Tensile Strength: 34 lbf/inch in width.

2.06 SECUREMENTS

A. Bands:

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Pabco-Childers Metals Corporation; Bands.
   b. RPR Products, Inc.; Bands.

2. Stainless Steel: ASTM A167 or ASTM A240/A240M, Type 304 or Type 316; 0.015 inch thick, 3/4 inch wide with wing seal.

3. Aluminum: ASTM B209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing seal.

B. Staples: Outward-clinching insulation staples, nominal 3/4-inch wide, stainless steel or Monel.

C. Wire: 0.062-inch soft-annealed, stainless steel.

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. Pabco-Childers Metals Corporation.
   c. RPR Products, Inc.
PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine substrates and conditions for compliance with requirements for installation and other conditions affecting performance of insulation application.

1. Verify that systems and equipment to be insulated have been tested and are free of defects.

2. Verify that surfaces to be insulated are clean and dry.

3. Proceed with installation only after unsatisfactory conditions have been corrected.

3.02 PREPARATION

A. Surface Preparation: Clean and dry surfaces to receive insulation. Remove materials that will adversely affect insulation application.

B. Coordinate insulation installation with the trade installing heat tracing. Comply with requirements for heat tracing that apply to insulation.

C. Mix insulating cements with clean potable water; if insulating cements are to be in contact with stainless-steel surfaces, use demineralized water.

3.03 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment and piping including fittings, valves, and specialties.

B. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of equipment and pipe system as specified herein or shown on the Contract Drawings.

C. Install accessories compatible with insulation materials and suitable for the service. Install accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.

D. Install insulation with longitudinal seams at top and bottom of horizontal runs.

E. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.

F. Keep insulation materials dry during application and finishing.

G. Install insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by insulation material manufacturer.

H. Install insulation with least number of joints practical.

I. Install insulation with factory-applied jackets as follows:

1. Draw jacket tight and smooth.
2. Cover circumferential joints with 3-inch-wide strips, of same material as insulation jacket. Secure strips with adhesive and outward clinching staples along both edges of strip, spaced 4 inches o.c.

3. Overlap jacket longitudinal seams at least 1-1/2 inches. Install insulation with longitudinal seams at bottom of pipe. Clean and dry surface to receive self-sealing lap. Staple laps with outward clinching staples along edge at 2 inches o.c.

4. Cover joints and seams with tape as recommended by insulation material manufacturer to maintain vapor seal.

5. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to pipe flanges and fittings.

J. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.

K. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

L. Repair damaged insulation facings by applying same facing material over damaged areas. Extend patches at least 4 inches beyond damaged areas. Adhere, staple, and seal patches similar to butt joints.

3.04 PENETRATIONS

A. Insulation Installation at Tunnel Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

3.05 FIELD-APPLIED JACKET INSTALLATION

A. Install metal jackets with a 2-inch overlap at longitudinal seams and end joints. Overlap longitudinal seams arranged to shed water. Seal end joints with weatherproof sealant recommended by insulation manufacturer. Secure jacket with stainless-steel bands 12 inches o.c. and at end joints.

3.06 FIELD QUALITY CONTROL

A. Testing Agency: Engage a qualified testing agency to perform tests and inspections.

B. Perform tests and inspections.

C. Tests and Inspections:

1. Inspect pipe, fittings, strainers, and valves, randomly selected by Resident Engineer, by removing field-applied jacket and insulation in layers in reverse order of their installation. Extent of inspection shall be limited to three locations of straight pipe, three locations of coupled fittings, two locations of flanges and one valve location.

D. All insulation applications will be considered defective or if sample inspection reveals noncompliance with requirements.

END OF SECTION
**PART 1 - GENERAL**

1.01 **SUMMARY**

- A. This Section includes specifications for furnishing, installing, and testing a partial standpipe system including, but not limited to wet standpipe piping, hangers and supports, fire hose valves (standpipes), automatic air vents, and sectionalizing valves.

- B. The provisions of the Section do not cover the connection to the municipal water supply, backflow preventer, alarm valve, or the permanent fire department connections. This work will be provided by a separate contract.

- C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
  1. Section 01 45 00, Quality Control
  2. Section 01 50 00, Temporary Facilities and Controls.
  3. Section 01 78 23, Operation and Maintenance Data.
  4. Section 01 57 24, Temporary Site Water Discharge
  5. Section 01 01 13, Shop Applied Coating For Metal.
  6. Section 05 50 00, Metal Fabrications
  7. Section 21 05 00, Common Work Results for Fire Suppression.
  8. Section 22 05 50, Mechanical Identification

1.02 **REFERENCES**

- A. This Section incorporates by reference the latest revisions of the following documents.
  1. American National Standards Institute (ANSI)
     a. B16.3 Malleable Iron Threaded Fittings
     b. B16.5 Pipe Flanges and Flanged Fittings
     c. B16.21 Nonmetallic Flat Gaskets for Pipe Flanges
     d. B31.1 Power Piping
  2. American Society of Mechanical Engineers (ASME)
     a. Boiler and Pressure Vessel Code (BPVC), Section IX, Welding and Brazing Qualifications
3. American Society for Testing and Materials (ASTM)
   a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   b. ASTM A105 Standard Specification for Carbon Steel Forgings for Piping Applications
   d. ASTM A183 Standard Specification for Carbon Steel Track Bolts and Nuts
   e. ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, 60000 PSI Tensile Strength
   f. ASTM A536 Standard Specification for Ductile Iron Castings

4. City of Seattle (COS):
   a. Seattle Fire Code (International Fire Code with Seattle Amendments)

5. Manufacturers Standardization Society for the Valve and Fittings Industry
   a. MSS SP-58 Pipe Hangers and Supports – Materials, Design and Manufacture
   b. MSS SP-69 Pipe Hangers and Supports – Selection and Applications
   c. MSS SP-89 Pipe Hangers and Supports – Fabrications and Installation Practices
   d. MSS SP-90 Guidelines on Terminology for Pipe Hangers and Supports

6. National Fire Protection Association (NFPA)
   a. NFPA 13 Standard for Installation of Sprinkler Systems
   b. NFPA 14 Installation of Standpipe and Hose Systems
   c. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: For each type of valve, pipe hanger, anchorage device and channel support system component.

C. Shop Drawings, and Manufacturers' product data including piping, fittings, valves, couplings, fire department connections, piping supports, maintenance data, and recommended spare parts. Show complete system in shop drawings, including construction phasing.

D. Pipeline layout drawings together with standard details.

1. Show on the line layout each standard pipe joint and each special joint or fitting by number and each hanger or support.
E. Certified Test Reports on Contractor's Material and Testing for underground piping in accordance with NFPA 13.

F. Operation and Maintenance Manuals: Section 01 78 23, Operation and Maintenance Data. In addition to these requirements include data for fire suppression valves and automatic air vents.

G. Welding Certificates.

H. Welding report interpreting weld radiographs to the Resident Engineer without recommendations.

1.04 QUALITY ASSURANCE

A. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."


2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

B. Employ shop and field welders and/or welding operators and welding procedures qualified in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

C. Employ a licensed fire protection installer to install standpipe system.

D. Verify materials are clearly marked with the manufacturer's name, nameplate data or stamp, rating, and ASTM conformance number, as applicable.

1. Use only fire protection system components and equipment that is Underwriters Laboratories (UL) Listed and labeled and Factory Mutual (FM) approved for use in fire protection systems. All piping materials shall as a minimum conform to the requirements of NFPA 13.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings

1. Conform to NFPA 14, NFPA 130 and amendments to these codes adopted by the Seattle Fire Department. Secure grooved end product from a manufacturer with ISO 9001 certification.

2. Pipe 2 Inches and Smaller: ASTM A53, Type S, Grade B or ASTM A106 seamless, Schedule 40, galvanized, threaded.

3. Pipe 2-1/2 Inches and Larger: ASTM A53, Type S Grade B, plain-end or grooved end, schedule 40, galvanized. For grooved end, use only factory- or field-formed square cut or rolled-formed grooves per coupling manufacturers specifications. Pipe joints where cut grooves are required are identified on the drawings.

4. Fittings 2 Inches and Smaller: Class 150 malleable iron threaded fittings conforming to ANSI B16.3. Conform to dimensions of ANSI B16.5.
5. **Fittings 2-1/2 Inches and Larger**: Ductile iron grooved end fittings conforming to ASTM A536 and as manufactured by the grooved end coupling manufacturer.

6. **Grooved Joint Piping System**: Mechanical grooved couplings for Pipe 2-1/2 Inches and Larger with grooved ends shall be flexible Victaulic Style 77 or rigid Style 07 type, hot dip galvanized from the factory and with Grade E, Ethylene Propylene Diene Monomer (EPDM) (negative 30 degrees F to 230 degrees F) standard style gaskets. Furnish coupling housings of ductile iron conforming to ASTM A536. For couplings from 2-inch through 6-inch size use couplings rated for a working pressure of at least 700 pounds per square inch (psi) and FM rated for 500 psi. Coupling Bolts and nuts: heat treated, zinc electroplated to ASTM B633 track-head style conforming to physical properties of ASTM A183 minimum tensile strength of 110,000 psi. Furnish all couplings and fittings from the same manufacturer.

7. **Flanges for 2-1/2 pipe and larger**: Class 150 forged steel, ASTM A105, weld neck, raised face or faced to match mating equipment or valves. Furnish gaskets with ANSI B16.21, 1/16-inch thick synthetic finish with nitrate builder. Flange Bolts: ASTM A307 Grade B bolts with A563 Grade A heavy nuts.

8. For all pipe and fittings described herein use only hot dip galvanized in accordance with Section 05 05 13, Shop Applied Coating For Metal. Furnish all mechanical grooved fittings hot dip galvanized from the vendors shop.

### B. Valves

1. **General**:
   a. Furnish and install valves shown on the Contract Drawings, specified or shown for the control and easy maintenance of piping and equipment. Provide valves having proper clearances; leak proof at the specified test pressure; maker's name or brand; the figure or list number; the guaranteed ANSI working pressure cast on the body and cast or stamped on the bonnet. Provide valves of a given type from one manufacturer except for special application.

   b. Provide gate valves suitable for repacking under pressure.

   c. Valves used for fire protection piping shall be listed for fire protection service.

2. **Ball Valves**: Provide ball valves for drain service size as indicated. Where low point drains are not indicated, provide a minimum 1 inch size drain and ball valve.

   b. Ball valve: UL Listed and FM approved and rated for 600 psi water-oil-gas (WOG)

3. **Butterfly Valves**: Designed for fire protection service with grooved ends, polyphenylene sulfide blend coated ductile iron body. Disc shall be ductile iron conforming to ASTM A536 with electrolysis nickel coating conforming to ASTM B-733. Furnish with nitrile (Grade T) seat conforming to ASTM D2000. Use only valves UL Listed for minimum 365 psi service in fire protection systems. Furnish valve with gear operated actuator and handwheel. Actuator shall have bronze traveling nut.
4. Fire Department Outlet Fire Hose Valves (FHV): 2-1/2 inch angle type cast brass; with a rough chrome plated finish, and valve rated to 300 psi. Furnish with red handwheel, female National Pipe Taper (NPT) inlet and the Seattle Fire Department compatible male hose thread outlet.
   a. Verify that valve is UL Listed and FM approved and furnish complete with brass cap and chain. Use fire hose valves of Elkhart Brass Model No. U-25-.25 or approved equal by Kidde Fire Fighting or the Waterous Company.

5. Fire Department Outlet Pressure Reducing Fire Hose Valves (PRFHV): 2-1/2 inch angle type valve for use on high pressure standpipes to control nozzle pressure; cast brass construction with a rough chrome plated finish, valve rated to 400 psi inlet pressure. Valve shall operate automatically depending on inlet pressure and flow. Furnish with red handwheel, female National Pipe Taper (NPT) inlet and the Seattle Fire Department compatible male hose thread outlet.
   a. Verify that valve is UL Listed and FM approved and furnish complete with brass cap and chain. Use fire hose valves of Elkhart Brass Model No. UR-25-2.5 or approved equal by Kidde Fire Fighting or the Waterous Company.

6. Valves shall be factory set in accordance with the schedule on the drawings and be capable of flowing 300 gpm at inlet pressures greater than 175 psig and less than 400 psig, with outlet residual pressures between 170 psig and 130 psig at the 300 gpm delivered flow.

C. Automatic Air Vents:
   1. Provided where automatic air vents of 1/2-inch size as indicated.
   2. Furnish Automatic Air Vents, Claval series 34 or approved equal by APCO or Crispin. For installation on vertical 1/2-inch threaded outlet connections off the top of the selected high points of the wet standpipe main.
   3. Air vents used in fire protection piping shall be UL listed or FM approved for fire protection service and rated for 400 psi working pressure.

D. Escutcheons:
   1. Split-hinged, locking type escutcheon held in place by either internal tension spring or a set-screw. Provide polished chromium-plated pressed steel material. Provide escutcheon to encompass the sleeve or opening.

E. Joint Pipe Couplings
   1. Grooved Joint Pipe Couplings: All pipe couplings shall be flexible-type except where rigid-type are indicated on the Contract Drawings.

F. Hangers & Supports:
   1. Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
      a. B-Line Systems, Inc.
b. Grinnell Corp.
c. GS Metals Corp.
d. National Pipe Hanger Corp.
e. PHD Manufacturing, Inc.

2. Pipe Hangers, Supports, and Components: MSS SP-58, factory-fabricated galvanized metallic coatings (hot dipped galvanized type) for support systems used in the tunnel.

3. Channel Support Systems: Consist of factory-fabricated components for field assembly as follows:
   a. Channel support shall be made from steel meeting the minimum mechanical properties of ASTM A1011 SS, Grade 33 and shall be hot-dip galvanized after fabrication in accordance with ASTM A123.
   b. All surface mounted struts in the tunnel shall be hot-dipped galvanized steel.
   c. Unless otherwise indicated on the Contract Drawings, surface mounted struts shall be 1-5/8-inch by 1-5/8-inch.
   d. Channel hole pattern shall accommodate attachment spacing and sized indicated.

4. All nuts, bolts, screws, clamps, brackets and miscellaneous fasteners in the tunnel shall be stainless steel.

G. Seismic Restraint Devices
   1. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an evaluation service member of ICC-ES an agency acceptable to authorities having jurisdiction.
      a. Structural Safety Factor: Allowable strength in tension, shear, and pullout force of components shall be at least four times the maximum seismic forces to which they will be subjected.

2. Channel Support System: MFMA-3, shop- or field-fabricated support assembly made of hot-dipped galvanized slotted steel channels and accessories for attachment to braced component at one end and to building or tunnel structure at the other end and other matching components and with corrosion-resistant coating; and rated in tension, compression, and torsion forces.

H. Attachments
   1. Refer to 21 05 00, Common Work Results For Fire Suppression

I. Structural Steel
   1. Refer to Section 05 50 00, Metal Fabrications, for structural steel.
PART 3 - EXECUTION

3.01 STANDPIPE COMPONENT INSTALLATION

A. Install the standpipe systems as indicated, in accordance with requirements of NFPA 14.

B. Install standpipe piping so that it can be thoroughly drained and, where practicable, arranged to drain at the main drain valves.

C. Valve accessibility for operation and servicing is required. Install valves as indicated and with no stems located below the horizontal position.

D. Provide escutcheon plates at finished surfaces where exposed piping passes through floors, walls, and ceilings. Fasten escutcheons to pipe or pipe coverings.

E. Install seismic restraints on piping. Comply with requirements in NFPA 13 for seismic-restraint device materials and installation.

F. Install listed fittings to make changes in direction, branch takeoffs from mains, and reductions in pipe sizes.

G. Install listed fire-protection valves, trim and drain valves, specialty valves and trim, controls, and specialties according to NFPA 14 and the authorities having jurisdiction.

H. Install listed fire-protection shutoff valves supervised-open, located to control or isolate sources of water supply as shown on the Contract Drawings. Install permanent identification signs indicating extent of system controlled by each valve.

3.02 APPLICATIONS

A. Grooved Joint Pipe Couplings: All pipe couplings shall be flexible-type except where rigid-type are indicated on the drawings.

3.03 HANGER AND SUPPORT INSTALLATION:

A. Pipe hanger and support installation shall conform to the following:

1. Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure or the tunnel structure.

2. Space supports as indicated in the drawings. Install additional supports at concentrated loads, including valves, flanges, guides, strainers, and expansion joints, and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms.

3. Install expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer’s written instructions.

4. Install hangers and supports complete with necessary inserts, bolts, rods, nuts, washers, and other accessories.

5. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of flexible couplings, expansion loops, expansion bends, and similar units.
6. **Load Distribution:** Install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

7. **Pipe Slopes:** Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.9, "Building Services Piping," are not exceeded.

### 3.04 CONSTRUCTION

#### A. Welding

1. Shop fabricate all major piping assemblies.

2. Field welding, in general, is not permitted. In specific cases and only with the approval of the Resident Engineer may the Contractor be allowed to field weld. Submit request to field weld with sufficient proof that no other method is feasible.

3. All welds shall have 100 percent penetration and smooth lines of fusion on the exterior and interior. Do not exceed 1/16-inch weld reinforcement.

4. Examine welds in accordance with the requirements of ANSI/ASW D1.1, Section 6, Parts A and B, and ASTM E94 and ASTM E1032, as applicable. In addition, examine by radiography 100 percent of the welds that are embedded in concrete or buried and examine fully by random radiography a minimum of 10 percent of all remaining circumferential butt welds.

#### B. Repair of Galvanized Surfaces:

1. Clean welds, bolted connections, field cut grooved pipe, and abraded areas such as rolled grooves on galvanized pipe and apply galvanizing-repair paint in accordance with Section 05 05 13, Shop Applied Coating For Metal.

### 3.05 IDENTIFICATION

#### A. Comply with the requirements of Section 22 05 50, Mechanical Identification.

### 3.06 FIELD QUALITY CONTROL

#### A. Testing

1. Perform 100 percent visual inspection of all field welds.

2. Test installed systems and products hydrostatically, using testing instruments calibrated by an Independent Testing Laboratory in accordance with Section 01 45 00, Quality Control, and flush after removal of testing equipment in accordance with applicable requirements of NFPA 14. Repair leaks and retest repaired parts of the system. Repair damages resulting from the system's failure during the test at no additional cost to Sound Transit.

   a. Test standpipe hydrostatically for two hours at the top most outlet. The test pressures for the standpipe system are as follows:

      1) Standpipe from UWS to Cross Passage No. 23: 360 psi.

      2) Standpipe from Cross Passage No. 23 to Cross Passage No. Brooklyn Station: 300 psi.
3) Standpipe from Brooklyn Station to Cross Passage No. 31: 300 psi.

4) Standpipe from Cross Passage No. 31 to Roosevelt Station: 300 psi

b. Contractor shall provide and dispose of the quantity of water necessary for testing. Refer to Section 01 57 24, Temporary Site Water Discharge, for testing water disposal requirements.

1) The contract may request permission from the Resident Engineer to allow water provided for hydrostatic testing to remain if performed subsequent to all required pipe flushing.

3. Conduct standpipe system flow test in accordance with NFPA 14 including but not limited to the following:

a. System demand testing shall conducted by flowing water at a rate of 300 gallons per minute at each installed pressure reducing fire hose valve and at any additional fire hose outlets required by the Seattle Fire Department.

4. Furnish items used in testing

a. Calibrate pressure gages.

b. Use testing instruments calibrated by a qualified laboratory in accordance with Section 01 45 00, Quality Control.

5. Perform tests in the presence of the Resident Engineer and Seattle Fire Department. Give 48-hour notice prior to test and notify the Seattle Fire Department and Seattle Public Utilities. The Resident Engineer will review certificates and test reports, and will inspect the standpipe system to verify conformance with NFPA 14.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for materials and installation common to piping systems specified in Division 22 including dielectric fittings, mechanical sleeve seals, sleeves, escutcheons, grouting, equipment, fire stopping sealant, supports and anchorages.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 23, Operation and Maintenance
2. Section 03 30 00, Cast-in-Place Concrete.
3. Section 05 05 13, Shop Applied Coatings For Metal
4. Section 05 50 00, Metal Fabrications.
5. Section 22 14 01, Drainage Systems for Structures.
6. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

1.02 REFERENCES

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

1. American Society for Testing and Materials (ASTM)
   a. ASTM A53 Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   b. ASTM A392 Zinc-Coated Steel Chain-Link Fence Fabric
   c. ASTM B32 Solder Metal
   d. ASTM B813 Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
   e. ASTM B828 Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
   f. ASTM D1785 Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
   g. ASTM D2235 Solvent Cement for Acrylonitrile-Butadiene-Styrene (ABS) Plastic Pipe and Fittings
h. ASTM D2564 Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
i. ASTM D2661 Acrylonitrile-Butadiene-Styrene (ABS) Schedule 40 Plastic Drain, Waste, and Vent Pipe and Fittings
j. ASTM D2672 Joints for IPS PVC Pipe Using Solvent Cement
k. ASTM D2846 Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Hot- and Cold-Water Distribution Systems
l. ASTM D2855 Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings
m. ASTM D3035 Polyethylene (PE) Plastic Pipe Based on Controlled Outside Diameter.

n. ASTM D3138 Solvent Cements for Transition Joints Between Acrylonitrile-Butadiene-Styrene (ABS) and Poly(Vinyl Chloride) (PVC) Non-Pressure Piping Components
o. ASTM D3139 Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
p. ASTM D3212 Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals

q. ASTM F402 Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings
r. ASTM F493 Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings

s. ASTM F656 Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings

2. American Society of Mechanical Engineers (ASME)
   a. ASME B1.20.1 Pipe Threads, General Purpose, Inch
   b. ASME B16.21 Nonmetallic Flat Gaskets for Pipe Flanges

3. American Welding Society (AWS)
   a. AWS A5.8 Filler Metals for Brazing and Braze Welding
   b. AWS D10.12 Guide for Welding Mild Steel Pipe
   c. AWS D1.1 Structural Welding Code
   d. AWS BRH Brazing Handbook

4. Copper Development Association (CDA)
   a. CDA Copper Tube Handbook

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
(A1) Product Data: For each type of product indicated. Include rating and classification, material descriptions, dimensions of individual components and profiles, and finishes for fire extinguisher and mounting brackets.

B. Welding Certification.

C. Operation and Maintenance Manuals: Submit operation and maintenance instructions and data for equipment provided under Division 22, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data.

1.04 QUALITY ASSURANCE

A. Steel Support Welding: Qualify processes and operators according to AWS D1.1.

B. Steel Pipe Welding: Qualify processes and operators according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

1. Comply with provisions in ASME B31.1, "Code for Pressure Piping."

2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe, Tube and Fittings

1. Joining Methods: Refer to Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances

2. Pipe Threads: ASME B1.20.1 for factory-threaded pipe and pipe fittings.

B. Joining Materials

1. Special Joining Materials if Not Listed Below: Refer to Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances

2. Pipe-Flange Gasket Materials: ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.

C. Dielectric Fittings: Combination fitting of copper alloy and ferrous materials with threaded, solder-joint, plain, or weld-neck end connections that match piping system materials.

1. Insulating Material: Suitable for system fluid, pressure, and temperature.

2. Dielectric Unions: Factory-fabricated, union assembly, for 250-pound-force per square inch gauge (psig) minimum working pressure at 180 degrees F.

3. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 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.

D. Mechanical Sleeve Seals: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

1. Sealing Elements: ethylene propylene diene monomer (EPDM) interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

2. Pressure Plates: Carbon steel. Include two for each sealing element.

3. Connecting Bolts and Nuts: Carbon steel with corrosion-resistant coating of length required to secure pressure plates to sealing elements. Include one for each sealing element.

E. Sleeves

1. Above Grade: Unless otherwise indicated on the drawings, provide steel pipe, ASTM A53, Type E, Grade B, Schedule 40, hot-dipped galvanized, plain ends.

2. Below Grade (or one side in contact with dirt): As detailed on Contract Drawings.

F. Grout: Refer to section 03 62 00 for grout specification.

G. Fire-Stopping Sealant: Material shall be asbestos-free and capable of maintaining an effective barrier against flame and gases. Provide joint sealants with fire resistance rating of minimum 2 hours, as determined per ASTM E 119, but not less than that equaling or exceeding the fire-resistance rating of the assembly in which firestop material is installed. Provide products with flame-spread values of less than 25 and smoke-developed values of less than 50, as determined per ASTM E 84.

1. Prepackaged, dry mixes consisting of a blend of inorganic binders, hydraulic cement, fillers, and lightweight aggregate formulated for mixing with water at Project site to form a non-shrinking, homogeneous mortar.

2. Silicone Sealants: Moisture-curing, single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below:

   a. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces and nonslag formulation for openings in vertical and other surfaces requiring a nonglumpling, gunnable sealant, unless indicated firestop system limits use to nonslag for both opening conditions.

   b. Grade for Horizontal Surfaces: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces.

   c. Grade for Vertical Surfaces: Nonslag formulation for openings in vertical and other surfaces.

H. Attachments:

1. Concrete and Masonry Anchor Bolts and Studs: Insert-type attachments with pull-out and shear capacities appropriate for supported loads and building materials where used, as follows:
a. Tunnel Anchor Bolts: Anchor bolts in the tunnel shall be stainless steel mechanical anchor type or epoxy anchor bolts. Both types shall be rated for dynamic loading.

b. Mechanical Anchor Bolts: Mechanical anchor bolts shall be stainless steel hex head finished bolt with a longitudinally tapered threaded end and a spring loaded multi-part conforming threaded expander nut. Anchor shall meet Fed. Spec. A-A 1923A for description of shield expansion (lag, machine and externally threaded wedge bolt anchors), Type 4. Expansion anchor elements shall be AISI 304 or 316 stainless steel. Anchors shall be Hilti Kwik Bolt 3 Expansion Anchor or approved equal.

c. Epoxy Anchor Bolts: Epoxy anchor bolts shall be stainless steel all-thread, encapsulated epoxy type with embedment length and drilled hole diameter per the manufacturer's recommendations. Polyester and vinyl resin is not acceptable. Anchors shall be Hilti HAS-E-SS or approved equal. Epoxy compound shall be Hilti RE-500 or approved equal and compliant with the 2006 International Building Code.

PART 3 - EXECUTION

3.01 PREPARATION

A. Obtain permits under Seattle Fire Department and as required by Seattle Fire Code for use of flammable liquids, hazardous materials, compressed gases, cutting and welding equipment.

3.02 ERECTION

A. Metal Supports and Anchorages

1. Refer to Section 05 50 00, Metal Fabrications, for structural steel.

2. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor plumbing materials and equipment.

3. Field Welding: Comply with AWS D1.1.

3.03 INSTALLATION

A. Piping Systems

1. Install piping according to the following requirements and Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances

2. Drawing plans, 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 by the Resident Engineer.

3. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and cross passages.
4. Install piping indicated to be exposed at right angles or parallel to structure walls. Diagonal runs are prohibited unless specifically indicated otherwise.

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 where indicated.

10. Select system components with pressure rating equal to or greater than system operating pressure.

11. Install sleeves for pipes passing through concrete and masonry.
   a. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations as indicated on the drawings
   b. Aboveground, Interior-Floor Pump Discharge Penetrations: Seal pipe penetration with silicone fire stopping sealant.
   c. Fire-BARRIER Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials.

12. Verify final equipment locations for roughing-in.

13. Refer to equipment specifications in other Contract Specification Sections for roughing-in requirements.

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 plumbing 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.

3.04 APPLICATION

A. Grouting

1. Mix and install grout for plumbing equipment base bearing surfaces, pump and other equipment base plates, and anchors.

2. Clean surfaces that will come into contact with grout.

3. Provide forms as required for placement of grout.
4. Avoid air entrapment during placement of grout.

5. Grout Placement:
   a. Completely filling equipment bases.
   b. Concrete bases: provide smooth bearing surface for equipment.
   c. Around anchors.

6. Cure placed grout.

3.05 CONSTRUCTION

A. Piping Joints: according to the following requirements and Section 22 14 01, Drainage Systems For Structures and Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances

1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.

2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

3. Threaded Joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. 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:
   a. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
   b. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.


5. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

B. Piping connections

1. Make connections according to the following, unless otherwise indicated:
   a. Install unions, in piping nominal pipe size (NPS) 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
   b. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.
   c. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

C. Repair of Galvanizing:
1. Refer to Section 05 05 13, Shop Applied Coatings For Metal, for galvanizing repair paint product specification, and the following:

a. Touching Up: Clean field welds and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.

b. Clean welds, bolted connections, field formed cut or rolled grooved pipe, and abraded areas and apply galvanizing-repair paint to comply with ASTM A780

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the means of identification of plumbing and fire protection equipment, piping, controls, and valves.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 23, Operation and Maintenance Data
2. Section 21 12 00, Fire Suppression Piping.
3. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

1.02 REFERENCES

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

1. American National Standards Institute (ANSI):
   a. ANSI A13.1 Scheme for the Identification of Piping Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit manufacturer's product data of pipe markers, valve markers or tags, equipment nameplates, and control nameplates.

C. 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 abbreviation (as shown on tag), location of valve (room, space, cross passage number, or tunnel station), and variations for identification (if any). Mark valves that are intended for emergency shut-off and similar special uses with "flags" in the margin of the schedule. In addition to mounted copies, furnish extra copies as required for maintenance manuals as specified in Section 01 78 23, Operation and Maintenance Data.

D. Samples: Submit samples of each color, lettering style, and other graphic representation required for each identification material or system.
PART 2 - PRODUCTS

A. MATERIALS

1. Pipe:
   a. Provide pipe markers of semi-rigid plastic that are accessible for maintenance operations (except piping in finished spaces). Include direction-of-flow arrows.
   b. Color code marker background with a clearly printed legend to identify the contents of the pipe. Colors and legend shall conform to ANSI A13.1.
   c. Provide pipe markers for the pump station discharge piping.
   d. The 6-inch standpipe piping will not be marked.

2. Valve Identification:
   a. Valve Markers: Satin finished aluminum faced black plastic backed, 1-1/2 inches in diameter. Letters shall be 1/4 inch high and numbers shall be 1/2 inch high; both shall be engraved. Marker fasteners shall be meter seals, four-ply 18 gage stainless steel wire, stainless steel "S" hooks, or meter seals. Markers shall bear identifications as indicated.
   b. Control Valves: Supervised OS&Y, butterfly valve markers, and fire hose valve (FHV) and pressure reducing fire hose valve (PRFHV) markers shall be satin finished aluminum faced black plastic backed, 2 by 4-inch, letters, and numbers shall be 1/4 inch high, engraved, identifying function as indicated.
   c. Valve List Frame: Crafted wood with clear glass front.
   d. Valve List: Provide on heavy white bond paper, either typed or printed.
   e. Valve List Closure: Crafted of transparent plastic. Front and back plastic sheets, which form closure, shall not be thinner than 15 mils. Two holes shall be punched at top of plastic closure to allow a nickel-plated bead chain to be affixed thereto.

3. Equipment Nameplates Including the Standpipe System Drain Valves and Air Vent Valves: Aluminum or stainless steel, where indicated, 2 inches by 4 inches, with a black enamel background and either etched or engraved lettering. Lettering shall be as indicated. Nameplates shall bear notations corresponding to the same notations on the framed wiring diagrams and operating instructions.

4. Control Nameplates: Laminated colored plastic with white lettering. Each switch shall have its switch positions clearly indicated and identified. Nameplates shall be worded to identify the respective item and function.
PART 3 - EXECUTION

A. INSTALLATION

1. Pipe Markers: Install adjacent to each valve and fitting, except on plumbing fixtures and equipment at each branch and riser take-off; at each pipe passage through wall, floor, and ceiling construction; at each pipe passage to underground; and on 25-foot centers on horizontal pipe runs.

2. Valve Markers: Fasten to valve body so as to be easily read.

3. Valve List Frame: Mount on a wall where indicated by the Resident Engineer. One valve list shall be mounted in the frame.


5. Control Nameplates: Mount with corrosion-resistant fasteners.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, and testing the tunnel track drainage system along the length of the tunnel structure and to the low point pump station as indicated, including embedded piping and drainage inlets. This Section also includes embedded seepage piping and cross passage drainage piping, including cross passage drains.

B. Related Sections: The work of the following Sections is related to the work of this Section.

1. Section 01 57 24, Temporary Site Water Discharge.
2. Section 01 78 23, Operation and Maintenance Data.
3. Section 05 13 00, Shop Applied Coatings for Metal.
4. Section 22 05 00 Common Work Results for Plumbing.
5. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

1.02 REFERENCES

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

1. American Society for Testing and Materials (ASTM)
   b. ASTM A74 Standard Specification for Cast Iron Soil Pipe and Fittings
   c. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

2. Uniform Plumbing Code and local amendments

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop drawings showing piping layouts, sizes, types, valves, drains, and cleanouts.

C. Manufacturers’ Product data for specified materials and equipment.

D. Equipment Manufacturer’s printed operating and maintenance instructions in accordance with Section 01 78 23, Operation and Maintenance Data, including detailed parts list, recommended spare parts list, and complete operation and maintenance procedures.
E. Certified test results and certificates of compliance as necessary to verify conformance with specified requirements.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings
   1. General: Provide pipe and fittings of sizes and configurations indicated.
   2. Tunnel Embedded Track Drainage Piping: Use Polyvinyl chloride (PVC), ASTM D1785, Schedule 80, Type I, Grade 1.
      a. Fittings: Same material and schedule as pipe.
   3. Seepage Drain Piping From Tunnel Walkway to Invert and Drain Piping Between Cross Passage Drains and Invert: High Density Polyethylene (HDPE), ASTM D 3035 or ASTM 2447.
      a. Pipe Working Pressure Rating: 160 psi water at 73 degrees F
      b. Pipe Thickness: Standard dimension ratio (SDR) of 11.

B. Trackway Drainage Inlets
   1. General: Drainage inlets include a sheet metal pan, grate and frame as detailed on the Contract Drawings.
   2. Sheet Metal Pan: Sheet metal, thickness as shown, galvanized to 0.45 oz/sq. ft. per side and in accordance with Section 05 13 00 – Shop Applied Coatings for Metal.
   3. Typical Track Drain Grate and Frame: Galvanized cast iron body, heavy-duty, 22 – inch x 22 -inch grate size, 1-3/4 -inch deep, minimum 1.7 square feet open area, Neenah R-4760 with angle frame and anchor studs, or equal.
   4. Track Drain at Cross Passage No. 31 Grate and Frame: Three-compartment custom fabricated grate and frame as indicated on drawings. Grates shall be heavy-duty with galvanized cast iron body. Each of two grates shall be 11 –inch x 22 –inch size, 1-3/4 – inch deep. The cleanout cover shall be galvanized steel checkered plate, ¼ -inch thick. Include drop handle welded to cleanout cover and designed to lift 40 lbs minimum. Grate openings and style similar to Typical Track Drain. Angle frame shall be shop-fabricated with anchor studs and hot-dipped galvanized.

C. Cross Passage Drains (DR-1 and DR-2)
   1. General: Commercial deck drain, double wall PVC base, removable slotted aluminum top and snap-in connection to base, Stegmeier Corp., or equal.
   2. Maximum Size: 2-inch wide by 4-inch deep.
   3. Accessories:
      a. Side adaptor with 1-1/2-inch drain connection and removable slotted aluminum top for cleanout.
b. Fernco coupling, or equal, with stainless steel clamps.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to installing or placing drainage products, clean excavations of water and extraneous material.

B. Clean interior of pipe, pipe fittings, drains, and cleanouts before installation.

C. Install sleeves through walls, floors, roofs, and other structures before installing drainage lines.

3.02 INSTALLATION

A. Install track drainage piping as indicated.

1. Prior to invert concrete pour, verify the slope of the piping conforms to the tunnel gradient or as otherwise indicated.

2. Install drainage piping prior to invert concrete pour on supports maximum 8 ft on centers such as channel iron or blocks and making sure to prevent point loading of the piping.

B. Install cross passage drain in accordance with manufacturer’s installation instructions, and as indicated. Provide necessary formwork and adjust drain sections so top of drain is flush with top of finished concrete floor.

3.03 FIELD QUALITY CONTROL

A. Testing

1. Do not cover products to be embedded in concrete until products have been inspections, tested, and accepted.

2. Test installed drainage lines and equipment as follows:

a. Piping may be tested in sections. Temporarily seal ends.

b. Cut pipe for drainage inlets after testing is successfully completed.

c. Fill gravity drains with water and allow to stand for not less than 30 minutes without leaking.

d. Repair leaks and retest systems until the system exhibits no leaks. Test with a water head of 30 feet for testing integrity of pipe.

e. Provide and dispose of water required for testing. Refer to Section 01 57 24, Temporary Site Water Discharge, for testing water disposal requirements.
3.04 CLEANING

A. Removing foreign material from the surfaces of products when cleaning. Leave the manufacturer’s labels intact. Flush all sections of the piping system and dispose of the flushing water from the tunnel using temporary pumps where necessary.

END OF SECTION
1.01 SUMMARY

A. This Section includes specifications for furnishing and testing the tunnel track drainage pumping station piping and appurtenances indicated for Cross Passage No. 31.

B. This Section includes specifications for furnishing the sump pump controller for installation in the Motor Control Center (MCC) specified in Section 26 29 13, Enclosed Controllers and MCC.
   1. Provide design, programming, graphic creation, material and labor for a complete and operable system. Coordinate electrical interface requirements with electrical subcontractor.

C. This Section includes specifications for furnishing liquid level sensors and level switches.

D. Refer to Section 01 50 00, Temporary Facilities and Controls, for requirement for temporary pumps at Cross Passage No. 31.

E. The final or permanent sump pumps will be provided in a future contract.

F. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 01 50 00, Temporary Facilities and Controls.
   2. Section 03 30 00, Cast-In-Place Concrete
   3. Section 22 05 00, Common Work Results for Plumbing
   4. Section 22 05 50, Mechanical Identification
   5. Section 22 14 20, Well Casing and Force Main
   6. Section 26 29 13, Enclosed Controllers and MCC
   7. Section 33 01 00, Operations and Maintenance of Utilities.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society for Testing and Materials (ASTM)
      a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dip, Zinc-Coated, Welded and Seamless
b. ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coating in Iron and Steel Products


d. ASTM A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

e. ASTM A536 Standard Specification for Ductile Iron Castings

f. ASTM B127 Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip

g. ASTM D2000 Standard Classification System for Rubber Products in Automotive Applications

2. American National Standards Institute (ANSI)

a. ANSI B18.10 Track Bolt and Nuts

b. ANSI B18.5 Round Head Bolts (Inch Series)

c. ANSI B18.22 Plain Washers

d. ANSI B16.1 Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800

e. ANSI B31.1 Power Piping

f. ANSI B40.1 Pressure Gauges and Gauge Attachments

g. ANSI A13.1 Scheme for the Identification of Piping Systems

3. American Water Works Association (AWWA)

a. ANSI/AWWA C104/A21.4 American National Standard for Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water

b. ANSI/AWWA C110/A21.10 American National Standard for Ductile-Iron and Gray-Iron Fittings, 3-inch through 48-inch, for Water and Other Liquids


e. ANSI/AWWA C150/A21.50 American National Standard for the Thickness Design of Ductile-Iron Pipe

f. ANSI/AWWA C151/A21.51 American National Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water
g. ANSI/AWWA C153/A21.53 American National Standard for Ductile-Iron Compact Fittings, 3-inch through 24-inch and 54-inch through 64-inch, for Water Service

h. AWWA C210 Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines

i. ANSI/AWWA C606 AWWA Standard for Grooved and Shouldered Joints

4. Federal Specifications
   a. WW-H-171E Hangars and Supports, Pipe
   b. WW-P-421 Pipe, Cast, Gray and Ductile Iron, Pressure (For Water and Other Liquids)

5. National Fire Protection Association
   a. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
   b. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit the following a minimum of 4 weeks prior to starting construction of the initial lining for the concrete wet well at cross passage number 31:

1. Calculations for pipe support and/or manufacturers load capacity data.

2. Manufacturer’s standard drawings and catalog cuts and certificates of conformance for the following items:
   a. Pipe and fittings
   b. Joints and couplings (including gaskets)
   c. Valves
   d. Gauges
   e. Wall sleeves
   f. Pipe to wall penetration closure
   g. Sump pump floor access hatches (including hardware)
   h. Programmable logic controller
   i. Level sensors, transmitters and float switches.
   j. Manufacturer’s installation instructions.

3. Provide technical details of the level sensor/transmitter for installation inside the MCC or control enclosure.
4. Shop Drawings. Show complete and accurate information of:
   a. Dimensioned piping layout, complete with locations of all supports, presented in tabular format with a description of each support type, at a minimum scale of 3/8 inch equal to 1 foot.
   b. Sump pump floor access hatches and cover dimensions.
   c. Fire- and smoke-damper installations, including sleeves.
   d. Coordinate dimension of piping and systems with the requirements of Section 31 71 23 Tunnel Excavation by Sequential Excavation Method.

1.04 OPERATION AND MAINTENANCE MANUALS:
   A. In accordance with Section 22 05 00, Common Work Results For Plumbing and Section 01 78 23, Operation and Maintenance Data. In addition to these requirements, include data for valves, sump pit appurtenances, PLC, level controls, propeller supply fan and combination fire smoke/damper.

1.05 COORDINATION
   A. Coordinate programming of PLC with installation of temporary pumps. Program sequence of operation

1.06 QUALITY ASSURANCE
   A. Determine specific locations and sizes for access doors needed to gain access to and remove sump pumps using the lifting rail.
   C. PLC Programming and Level Sensor Installation: All work associated with the products, programming and testing specified herein must be accomplished by trained mechanics and electricians in the continuous employment of a firm whose normal business is the installation and maintenance of automation control systems instrumentation.
   D. Tests. Perform all tests required by applicable referenced publications, whether specified in that publication to be mandatory or otherwise. For tests which are not specified in the referenced publication to be performed at definite intervals during manufacture, verify tests have been performed within three years of the date of submittal of certificates on the same type, class, grade, and size of material as is being provided for the project.

1.07 DELIVERY, STORAGE, AND HANDLING
   A. Promptly remove damaged products from the job site. Replace damaged products with undamaged products.
   B. Load and unload all pipe, fittings, valves, and appurtenances by hoists or skidding. Do not drop products. Do not skid or roll products on or against other products. Use pad slings, hooks, and pipe tongs in such a manner to prevent damage to products.
C. Keep stored products safe from damage or deterioration. Keep the interior of pipe, fittings, valves, and appurtenances free from dirt or foreign matter. Drain and store valves in a manner that protects valves from damage by freezing. Store gaskets, plastic pipe and fittings, and other products, which deteriorate with sunlight in a cool location, out of direct sunlight. Do not allow gaskets to come in contact with petroleum products.

D. Store valves and appurtenances in accordance with manufacturer's recommendations.

E. Stack ductile iron, plastic, and steel pipe according to the requirements of the pipe manufacturer. Do not stack fittings, valves, or valve stands.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Furnish all pipe, fittings, and appurtenances as indicated and specified in this Section. For all pipe, fittings, valves, and appurtenances use only new products.

2.02 NON-BURIED PIPE AND FITTINGS

A. Non-Buried (Exposed) Pipe:
   1. Located within the pump station, inside the wet well and the cross passage.
   2. Grade C ductile iron: AWWA C151, as modified by Fed. Spec. WW-P-421.
   3. Minimum metal wall thickness of Class 53 for flanged or grooved wall pipe.
   4. Coated in accordance with “Pipe Coating” article within these specifications.
   5. Flanged pipe:
      a. AWWA C115.
   6. Cement mortar lining: AWWA C210 Type V cement.

B. Non-Buried Joints:
   1. Mechanical grooved type joints or flange joints with screwed on ductile iron flanges where required for connection to flanged valves.
      c. Field made-up flanges: not allowed.

C. Non Buried Fittings:
   1. Designed and manufactured for a minimum pressure rating of 250 pounds per square inch (psi).
   2. Mechanical grooved ends.
   3. Flange joints conforming to ANSI/ AWWA C110.
4. Grooved type joints: ANSI/AWWA C110, for center to end dimensions and AWWA C153 or ANSI 21.10/AWWA C-110 for wall thickness.

5. Lining cement mortar: AWWA C210 Type V cement.

6. Factory furnished exterior coating equal to that of the connecting pipe.

2.03 PIPE COATING:

A. Applied to the exterior surfaces of wet well and cross passage ductile iron pipe and fittings in accordance with AWWA C210:

1. Factory applied primer coat equal to MC- Ferro Clad.
   a. Prime Coating Thickness: Minimum 3 mils to 5 mils DFT (dry file thickness).

2. Factory applied intermediate coat equal to MC Ferrox B 200.
   a. Intermediate Coating Thickness: Minimum 3 mils to 5 mils DFT.

3. Factory applied final coat equal to MC Ferrox A 200.
   a. Final Coating Thickness: Minimum 2 mils to 4 mils DFT.

4. The prime, intermediate and final coats will be compatible with each other.

2.04 NON-BURIED GROOVE-TYPE MECHANICAL COUPLINGS:

A. Coupled with grooved ends by engaging and holding these ends to form a watertight joint by means of a bolted, segmental clamp housing enclosing a sealing gasket.

B. Provide a rigid joint comparable to a flanged system.

C. Clamp housing:

1. Two or more parts made of ductile iron conforming to ASTM A536.

2. Minimum 400 psi working pressure for 8-inch diameter pipe and smaller.

3. Bolts and nuts for connecting clamp housing connections:
   a. Track bolts and nuts conforming to ANSI B18.10
   b. Roundhead, square neck type conforming to ANSI B18.5
   c. Hex nuts conforming to ANSI B18.22
   d. Zinc plated to ASTM B633

4. Bolt holes: of a shape to hold fast the necks of the bolts used

D. Gaskets:

1. Halogenated Butyl rubber, flush seal type, conforming to ASTM D2000

2. Supplied by the coupling vendor.
3. Shaped to effectively seal joint against leakage, when compressed.

E. Grooved ends of piping: In accordance with the published recommendations of the manufacturer of the coupling, as approved by the Resident Engineer.

F. Strength of coupling: Not less than that of the pipe.

G. Housing covered with factory applied, enamel coating.

2.05 GROOVE-TYPE MECHANICAL FLANGE ADAPTERS:

A. Join pipe and fittings with grooved ends to flanged valves and other equipment.

B. Engage groove in pipe or fitting and hold this end to the adjoining flange to form a rigid, watertight joint.

C. Clamp housing: Two or more parts made of malleable iron conforming to ASTM A536

D. Bolts and nuts: Heavy hex cadmium plated steel.

E. Gasket: Halogenated Butyl and supplied by the flange adapter manufacturer.

F. Flange washer: Between the flange adapter gasket and the flange or flange gasket if so stipulated by the adapter manufacturer.

G. Flange: Conform to ANSI B16.1: Class 125 drilling.

H. Coating of the flange adapters: Equal to the approved coating for the grooved couplings.

2.06 FLANGE JOINT ACCESSORIES:

A. Gaskets for flange joints: See Section 22 05 00, Common Work Results For Plumbing.

B. Nuts and bolts: Zinc plated steel, heavy hex nuts.

2.07 BURIED PIPE AND FITTINGS:

A. Pump station force main pipe installed in well casing at Cross Passage No. 18 and buried pipe to the grade level sewer manhole in East Roanoke Street, is specified in section 22 14 00, Well Casing and Force Main.

2.08 DISCHARGE DRAIN PIPING:

A. Pump station drain piping from each pump discharge riser to the sump.

B. Hard Copper Tube: ASTM B 88, Type K, water tube, drawn temper.

C. Copper Pressure Fittings: ASME B16.18, cast-copper-alloy or ASME B16.22, wrought-copper, solder-joint fittings. Furnish wrought-copper fittings if indicated.

D. Copper Unions: MSS SP-123, cast-copper-alloy, hexagonal-stock body, with ball-and-socket, metal-to-metal seating surfaces, and solder-joint or threaded ends.

2.09 VALVES

A. Furnish all isolation, check and drain valves, shown on the discharge side of the sump pumps, as indicated and specified herein.
B. Plug Valves:

1. Eccentric plug type unless otherwise indicated or specified herein

2. Valves:
   a. Non-lubricated eccentric type with Neoprene resilient faced plugs
   b. Furnished with flanged end connections.
   c. Flanges: Faced and drilled to the ANSI 125/150 standard.
   d. Valve bodies:
      1) Rectangular ported design and made of ASTM A126 Class B cast iron and with bolted bonnets.
      2) Furnished with welded overlay seats of not less than 90 percent pure nickel.
      3) Seat area: raised with surface completely covered with weld to ensure that the plug face contacts only nickel.

3. Plug:
   a. ASTM A126 Class B cast iron.
   b. Cylindrical seating surface eccentrically offset from the plug shaft.
   c. Interference between the plug face and the body seat externally adjustable in the field with the valve in the line under pressure.


5. Stem seals:
   a. Multi-V ring adjustable packing type
   b. Replaceable in-line without valve disassembly.

6. Port area: Not be less than 80 percent of the mating pipe area.

7. Gear operated requiring not more than 50 pounds force (lbf) at the rim of the hand wheel under all operating conditions.

8. Furnished with travel stops for the full open and closed positions and provided with intermediate position indication in 15-degree increments.

9. Rated for minimum 175 psi working pressure.

C. Swing Check Valves:

1. ASTM A126 Class B cast iron, with steel reinforced, Buna-N rubber lined flapper with bubble-tight seating.

2. Unrestricted flow area
3. 125-pound class rating and a 175-psi working pressure.

4. Inside of the valve: Rubber lined such that internally the valve has no exposed metal surfaces.

5. Positive non-slip backflow device, for the purpose of backflushing the pumps.

6. Phenolic primer red oxide exterior coating.

7. Swing check valve: APCO Series 100R or approved equal

D. Ball Valves:

1. 2 inches and smaller for drain service:
   a. ASTM A126, Class B Cast iron body
   b. Threaded end connections.

2. ASTM A126 Class B Cast iron or ASTM A536 ductile iron ball.

3. Seats: Cast Monel, ASTM B127 or BUNA-N rubber

4. Packing: TFE V-flex

5. Tested to the design working pressure (150 psi) with the ball in the closed position to determine tightness of the ball and seats.

E. Actuated Drain Valve:

1. 2-way solenoid valve, pilot-operated, 3/4-inch NTP connection, 3/4-inch orifice size, brass body, PTFE seals and disc, stainless steel wetted parts, 300 PSI operating pressure, watertight enclosure, UL listed for general purpose valve, ASCO 8210 Series, G
   a. Power: 120 VAC, 48 VA holding, 240 VA inrush

2.10 HANGERS AND SUPPORTS


B. Stainless steel materials in the sump areas and stainless steel or hot-dip galvanized pipe hangers and supports in the cross passages.

2.11 PIPING APPURTEANCES

A. Gauges: ANSI B40.1, single style pressure gauge for water with 4.5-inch dial, brass or aluminum case, bronze tube, gauge cock and pressure snubber. Provide scale range suitable for the intended service.

B. Sleeves in masonry and concrete walls, floors, and grade beams: Refer to Section 22 05 00, Common Work Results for Plumbing, for product specification.

C. Pipe to Exterior Wall and Pipe to Exterior Floor Mechanical Sleeve Seals: Refer to Section 22 05 00, Common Work Results for Plumbing, for product specification.
D. Miscellaneous Steel:
1. Pipe supports, hangers, anchors, sleeves, and associated steelwork:
   a. Hot-dip galvanized in accordance with ASTM A153, 2 ounces per square foot minimum.
   b. Configured as indicated

E. Attachments: Refer to Section 22 05 00 Common Work Results For Plumbing.

2.12 PIPING IDENTIFICATION:
A. Refer to Section 22 05 50, Mechanical Identification, for pipe marker material specification.
B. Indicate flow direction with arrows adjacent to labels.
C. Spacing no greater than 10 feet.

2.13 SUMP PIT APPURtenances
A. Aluminum Angle Frame Sump Access Hatch:
   1. Performance Requirements: Provide triple leaf access door and frame assemblies manufactured as integral units ready for installation.
      a. Opening Size: The nominal hatch size and clear inside opening is indicated on the Contract Drawings.
      b. The hatch shall be designed to provide fall through protection per OSHA standard 1910.23 and controlled confined space entry per OSHA standard 1910.146.
   2. Fabricate to support 600 pounds per square foot minimum live load.
   3. Cover: Reinforced 1/4-inch type 5086 aluminum diamond plate with steel hold open arm that automatically locks cover in a 90-degree open position. A removable exterior turn/lift handle with spring loaded ball detent shall be provided to open the cover.
   4. Design of access hatch shall incorporate a triple leaf configuration, allowing each leaf to operate independently. Frame shall be a one piece unit.
   5. Frame: Extruded aluminum, with a continuous 1-1/2-inch anchor flange. Include additional supports at mid-points as determined by hatch manufacturer for hatch configuration indicated on drawings.
   6. Hinges: Stainless steel with a 3/8-inch grade 316 stainless steel pin. Hinges shall be bolted to the angle frame and diamond plate, with grade 316 stainless steel bolts and ny-lock nuts.
   7. Hardware: 316 stainless steel recessed Slamlock, with keyway protected by a threaded stainless steel plug. Plug shall be flush with the top of the 1/4 inch diamond plate. Slamlock shall be fastened with grade 316 stainless steel bolts and washers. Provide a separate recessed padlock clip with hinged access cover. Provide recessed lift handle flush with top of cover.
8. Safety Grate: The grating shall be designed to withstand pedestrian (300 PSF) loading. The sump access hatch design shall assure the safety grate is in place before the cover can be closed. Each grate shall be hinging system and shall lock in the 90-degree position once opened. Grate shall be coated with OSHA type safety orange color two part epoxy paint.

B. Steel Angle Frame Catch Basin Access Cover:
   1. Curb Frame Material: 1/4 inch steel angle with strap anchors welded to exterior.
   2. Cover Material: Steel diamond plate with steel flush lifting handle that does not protrude above the cover.

C. Access Ladder:
   1. Ladder Material: 6061-T6 Aluminum
   2. Ladder Design: Shop fabricated ladder shall comply with OSHA Standard 1910.27. Include supports for connection to concrete wall as indicated on the Contract Drawings.
   4. Attachments: Anchor bolts as indicated on Contract Drawings. See Section 21 05 00, Common Work Results For Fire Suppression, for anchor bolt specification.

2.14 PROPELLER SUPPLY FAN

A. Propeller fans shall have wheels constructed of either steel or aluminum blades with hubs, mounting rings and plates that are cast or die formed and with smooth curves where the air enters the wheels.

B. Propeller fans shall be provided complete with motors and fan guards. Fans and motors shall be mounted on resilient supports and heavy steel frame. Steel angles and plates shall be provided to mount fans and dampers in wall openings. Mounting plates shall be designed to prevent distortion and shall be either turned up at edges or braced with steel angles.

C. Shafts for fans shall be steel. Bearings for fan shafts shall be permanently lubricated, permanently sealed, ball bearings.

D. Fan wheels shall be mounted on either extended motor shafts or ball-bearing hubs that rotate on fixed stub shafts; support shafts by two self-aligning bearings.

E. Fans shall be belt-driven or direct-driven as indicated. Motor mounting for belt driven units shall be resilient and shall be adjustable for correction of belt tension.

F. Propeller fan shall have a motor with nameplate rating not less than the brake horsepower required to drive the fan with a static pressure 0.20 inch greater than the value scheduled on the Contract Drawings.

2.15 COMBINATION FIRE SMOKE DAMPER

A. Manufacturers: Ruskin, Prefco, NCA Mfg, or Air Balance, Inc.
B. General: Labeled to UL 555 "Standard for Fire Damper" for 1-1/2 hour fire damper. Open and close under operating conditions up to 4-inches w.g. in closed position and 2000 fpm in open position. Class 2 leakage rating. Automatic remote reset after test, smoke detection or power failure.

C. Fire Rating: 1-1/2 hours.

D. Fusible Link: Replaceable, 165 degrees F rated unless specifically indicated 212 degrees F or 285 degrees F.

E. Frame: Minimum 16-gauge thick, galvanized, sheet steel.


G. Mounting Sleeve: Factory-installed, minimum 20-gauge thick, galvanized, sheet steel; length to suit wall or floor application.

H. Blade Position Indicator Switch: Provide blade position two-position indicator switch for remote monitoring of blade position.

I. Damper Actuator: Factory installed. 120 Volt, single phase, 60 hertz electric actuators; actuator and linkage located out of air stream; Fail closed. Provide manufacturer’s re-settable fuse link and switch package.

2.16 PUMP CONTROLLER

1. General Requirements: Furnish a programmable logic controller (PLC) for installation in the cross passage no. 18 motor control center by the Section 26 29 13, Enclosed Controllers and MCC, contractor for control and monitoring of the tunnel sump pump station. Identify the system as the Track Drainage Pump Control System. The PLC will be mounted in the MCC as shown on the electrical Contract Drawings.

2. The Track Drainage Pump Control System shall include the stand-alone PLC equipment racks, sensors, operating software, operator training, installation labor, programming, warranty and all other necessary material and labor to provide a complete and workable pump control system. Coordinate interface requirements with electrical Contractor.

3. Use stand-alone PLC controllers, microprocessor-based, with a minimum word size of 16 bits, multi-tasking, multi-user, real-time digital control processors consisting of modular hardware with plug-in enclosed processors, communication controllers, power supplies and input/output point modules. Controller size: Sufficient to fully meet the requirements of this specification and Section 26 29 13 and with spare capacity and expandability features as described below.

4. Each PLC controller: Sufficient memory to support its operating system and databases including all required trending, communications, alarm management and manual override monitoring.
5. Each PLC controller: Support monitoring and control of the following types of points:

   a. Analog Inputs (AI):
      1) 4-20 mA
      2) 0-50 mVdc
      3) 0-10 Vdc
      4) 100 ohm RTD’s

   b. Digital Inputs (DI):
      1) Dry Contact Closure
      2) Pulse Accumulator
      3) Voltage Sensing

   c. Digital Outputs (DO):
      1) Contact Closure (Interposing relays as required)

   d. Analog Outputs (AO):
      1) 4-20 ma
      2) 0-10 Vdc

6. Each PLC controller: Minimum of one spare of each point type (analog inputs, digital inputs, analog outputs, digital outputs). Provide all processors, power supplies and communication controllers complete so that the implementation of a new point only requires the addition of the appropriate point input/output termination module and wiring. Provide sufficient internal memory for the specified control sequences and have at least 25 percent of the memory available for future use.

7. PLC controllers: Provide local LED status indication for each digital input and output for constant, up-to-date verification of all point conditions without the need for an operator I/O device. Provide graduated intensity LED’s or analog indication of value for each analog output. Provide communications module capable of communicating all process data via Internet Protocol (IP) over Ethernet.

8. PLC controllers: Provide at least two RS-232C serial data communication ports for operation of operator I/O devices such as industry standard printers, operator terminals, modems and portable laptop operator’s terminals.

9. The PLC controller: Continuously perform self-diagnostics, communication diagnosis and diagnosis of all associated panel components, and provide local annunciation of any detected component failures or low battery conditions.

10. Provide a flat-panel operator interface terminal mounted on the front of the MCC and connected to the enclosed PLC processor. Furnish terminal with color pixel-based graphics and functionality to dynamically display and modify all process parameters being monitored by the PLC processor. Provide all necessary
programming to display process equipment and all associated controlled and monitored process variables including annunciation of alarm conditions. For operator interface terminal use Allen-Bradley Panel View 600 Color, or equal.

11. The Track Drainage Pump Control System: Integrated into the Field Control System. Terminate control wiring from pump control system located in the MCC to a terminal strip inside the Interface Terminal Cabinet. MCC and Interface Terminal Cabinet are located at Cross Passage No. 18 as shown on the drawings. See the sequence of operation in Part 1 of this Section for interface requirements from the Track Drainage Pump Control System to the Interface Terminal Cabinet.

12. Provide all necessary programming development software and control logic configurations as an integral part of the PLC controllers configure such that they are not dependent upon any higher level computer for execution. All programs: Executed automatically without the need for operator intervention, and flexible enough to allow user customization. Programming logic and configuration: Applied to tunnel equipment as described in Part 3, Execution, herein.

13. Pump Controller: Allen-Bradley Control Logix 1756 or approved equal.

2.17 LEVEL TRANSMITTER:
A. Solid-state, microprocessor-based, head pressure sensing, utilizing a variable capacitance transducer element suitable for continuously submerged operation.
B. Housing: Type 316 stainless steel
C. Sensors:
   1. Rated for operation at negative 40 degrees C to 80 degrees C.
   2. Loop powered
   3. Provide a 0 to 50 mVdc output signal in response to a field adjustable input span (0-30 pounds per square inch gage (psig) maximum).

2.18 FLOAT SWITCHES:
A. High density polyethylene float body
B. Approximately 4.5 inches in diameter
C. Mercury-to-electrode type tilt switch rated at 4.5 Amperes at 120 Volts AC.
D. Float: Permanently marked to identify contacts as normally open or normally closed.
E. Manufacturer: Anchor Scientific Inc. Type S or approved equal.
F. Supply with heavy-duty No. 18/2 type SO cable with synthetic rubber or PVC jacket.
   1. Cable: Long enough to reach track drainage pump control panel without any splices.

2.19 CONTROL WIRING:
A. In accordance with Section 26 05 25, Wire and Cable, and all applicable codes.
B. Ground equipment and devices in accordance with manufacturer’s recommendations to prevent ground loops.

C. Control Wiring:
   1. 24 V Circuits: Insulated copper 18 AWG minimum, rated for 300 VAC service.
   2. 120 VAC: 14 AWG minimum, rated for 600 VAC service.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Piping
   1. In accordance with the general requirements for installation of pipelines and with the applicable requirements of ANSI/ASME B31.1, except as otherwise specified or as indicated. Installed piping on supports as indicated, provide additional supports as required by the applicable standards. Coat all flange bolts with anti-seize compound.

B. Pipe Laying and Jointing
   1. Clean pipe and fittings to free from fins and burrs. Before placing in position, clean pipe, fittings, valves, and accessories, and maintain in a clean condition.
   2. Provided equipment for lowering sections of pipe into position. Do not, under any circumstances, drop or dump pipe, fittings, valves, or any other water line material into the work area.
   3. Cut pipe accurately to measurements established at the site and work into place without springing or forcing. Replace pipe or fitting that does not allow sufficient space for installation of jointing material with one of acceptable dimensions.
   4. Provide anchors and support as indicated.
   5. Keep the wet well free of water until force main has been connected and pipe through floor closures have been completed.
   6. Seal open ends of pipe temporarily with plastic or wood end caps or bulkheads.
   7. Repair any erection damage to pipe lining in accordance with AWWA C104.
   8. Repair pipe coatings as recommended by pipe coating manufacturer’s recommendations.

C. Flanged Joints
   1. Tighten flanged joints and flanged adapter joints. Avoid undue strain on flanges, valves, fittings, and other equipment and accessories. Align bolt holes for each flanged joint. Use full size bolts for the bolt holes. Do not use undersized bolts. Ensure adjoining flange faces are not out of parallel to such degree that the flanged joint cannot be made watertight without overstraining the flange. Replace
any flanged pipe or fitting whose dimensions do not allow connecting of a flanged joint as specified.

D. Grooved Pipe

1. Where grooved pipe is employed, perform as much grooving as possible in shop under controlled conditions. Make field grooves with equipment recommended by the manufacturer of the couplings. Where required to allow for alignment of piping systems, install pipe with end separation between straight pipe lengths of that listed for flexible radius cut grooves.

E. Valves

1. Install all valves in locations as indicated and in accordance with manufacturer's written instructions.

F. Hanger and Support

1. Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure or the tunnel structure.

2. Support piping at points as indicated with type of hanger indicated and elsewhere as required by the Contract Specifications and the referenced standards.

3. Unless otherwise indicated in the Contract Drawings, space attachments within maximum piping span length indicated in MSS SP-69. Install additional supports at concentrated loads, including valves, flanges, guides, strainers, and expansion joints, and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms.

4. Vertical Piping: Support at floor and at not more than 10-foot intervals.

5. Horizontal Piping: Support as indicated. Support the 3-inch diameter cast iron drain line and all other lines smaller than 3 inches in diameter at a maximum spacing of 7 feet. Support cast iron drain with one hanger close to joint on the barrel.

G. Pipe Sleeves

1. Provide pipe sleeves where piping passes through walls or ceilings.

2. Determine the required inside diameter of each individual wall opening or sleeve before ordering, fabricating or installing any pipe or sleeve. Size the inside diameter of each wall opening as recommended by the manufacturer to fit the pipe to wall sleeve closure, to ensure a watertight joint. Sizing may be obtained through manufacturer's catalog.

3. Secure sleeves in proper position and location during construction. Provide sleeves of sufficient length to pass through entire thickness of walls or roofs. Install sleeves in locations as indicated and in locations necessary to install piping.
H. Anchorage

1. Provide anchorage for fastening work securely in place. Set anchors in concrete as the work progresses and space as indicated. If anchors are needed, but not indicated, obtain approval for sizes, types, and spacing of anchors from the Resident Engineer prior to installation. Anchorage not otherwise specified or indicated includes slotted/embedded inserts, expansion shields, drop-in-anchors; toggle bolts and through bolts for masonry; machine and carriage bolts for steel; through bolts and lag bolts. Provide inserts of suitable and approved types where required for support or anchorage of equipment and finish construction.

a. Inserts: stainless steel unless indicated or specified otherwise

b. Slotted inserts: 12 gauge stainless steel of types required to engage with anchors

c. Anchors and anchor bolts in walls: stainless steel conforming to ASTM A276 or ASTM A493, AISI Type 316 conforming to ASTM F594, AISI Type 316 with stainless nuts. Use stainless steel lock washers under all nuts.

I. Pipe to Wall Penetration Closure

1. Install pipe to wall penetration closure in accordance with manufacturer's written instructions. Bolt heads for wall closures must be inside the pump station, bolt heads for floor closures must be on the inside of the sump.

J. Access Hatches and Covers:

1. Comply with manufacturer's written instructions for installing access doors and frames.

2. Set frames accurately in position with plane of top surface aligned with adjacent finish surfaces.

K. Fire Smoke Dampers

1. Install combination fire/smoke, fire and smoke dampers according to manufacturer's UL-approved written instructions and coordinate with electrical for operation and monitoring requirements.

3.02 LEVEL SENSORS:

A. Install float switches and level transducer per manufacturers installation instructions.

B. Adjust level transmitter and float switches to actuate at levels indicated by temporary pump supplier.

3.03 PLC PROGRAMMING

A. Provide design, programming and graphics generation for PLC control of temporary drainage pumps at cross passage no. 18:

1. Provide programming to meet sequence of operation for temporary pumps including the analog inputs for water level from the level transmitter, digital input from float switches
2. Alarm Points: Digital alarm input from float switches for high or low water level shall initiate an alarm.

3. Provide all dynamic graphic display at operator interface terminal.

3.04 FIELD QUALITY CONTROL

A. Hydrostatic Test

1. Pressure Piping:
   a. As a minimum, meet the requirements of ANSI B31.1 unless more stringent requirements are indicated herein.
   b. Use testing instruments calibrated by a qualified laboratory in accordance with Section 01 45 00, Quality Control.
   c. Provide and dispose of all water necessary for testing. Refer to Section 01 57 24, Temporary Site Water Discharge, for testing water disposal requirements.

2. Ductile Iron Piping:
   a. Fit ends of piping being tested with test plugs, caps or blind flanges with a tap of adequate diameter to fill and pressurize the system with water.
      1) Test plugs or caps or blind flanges: Capable of withstanding an internal pressure of 150 psi.
   b. Remove any instruments or other items that may be damaged by the test pressure.
   c. Fill all piping with water and expel all air from the piping. Tap the piping at high points, if necessary, to release all air from the piping.
   d. Apply 30 psi for 8 consecutive hours to allow the cement lining to absorb moisture. Add water as required to make up loss.

3. Ductile Iron Piping and Stainless Steel Force Main Riser to Surface:
   a. Test piping at a static pressure of 120 psi over a period of not less than 4 consecutive hours.
   b. Considered the test successful when the pressure drop over the test period is 5 psi or less.
   c. Repair all leaks and repeat the test until the pressure drop over the test period is 5 pounds per square inch or less.
   d. Remove all test equipment and plug all test holes at completion of test. Replace plugs watertight.
B. PLC Testing

1. Demonstrate compliance with sequence of operation and the Contract Drawings. Calibrate instrumentation and controls and verify the specified accuracy using calibrated test equipment. Adjust controls and equipment to operate temporary pumps to meet the sequence of operation. Furnish personnel, equipment, instrumentation, and supplies necessary to perform calibration and site testing. Ensure that tests are performed by competent employees of the PLC system installer or the system manufacturer’s representative regularly employed in the testing and calibration of such systems. Submit a report detailing the results of all performance, functional, and diagnostic tests and calibrations to the Engineer for final system acceptance.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing a well casing and pump station force main piping from Cross Passage No. 31 to the private manhole MH-2 indicated on the Contract Drawings.

B. This Section includes the following:
   1. Rotary drilled, reverse-rotary drilled, or air-rotary drilled well and casing.
   2. Force main piping.

C. Related Sections: The work of the following Sections is related to the work of this Section.
   1. Section 01 57 13, Temporary Erosion and Sediment Control.
   2. Section 01 57 15, Temporary Construction Noise and Vibration Control.
   3. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.
   4. Section 31 20 00, Earth Moving.

1.02 REFERENCES

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

   1. American Society for Testing and Materials (ASTM)
      a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
      b. ASTM A182 Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
      c. ASTM A312 Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
      d. ASTM A403 Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
      e. ASTM A778 Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
      f. ASTM C33 Standard Specification for Concrete Aggregates
      g. ASTM C150 Standard Specification for Portland Cement
2. American Society of Mechanical Engineers (ASME)
   a. Boiler and Pressure Vessel Code, Section IX: Welding and Brazing Qualifications

3. American Water Works Association (AWWA)
   a. AWWA A100 Standard for Water Wells

4. American Welding Society (AWS)
   a. AWS B2.1 Standard Welding Procedure Specification

5. Washington Administrative Code (WAC)
   a. Title 173 WAC

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data:
   1. Indicate the maximum allowable operating pressure and temperature of each component and any related manufacturing standard.
   2. For pipe and fittings.

C. Submit work plan including the drilling method,

D. Shop Drawings: Show layout and connections of casing and force main piping from Cross Passage 18 to manhole MH-2.

E. Project Record Documents: Record the following data for pump station casing and force main:
   a. Casings: Material, diameter, thickness, weight per foot of length, and depth below grade.
   b. Log: Formation log indicating strata encountered.
   c. Alignment: Certification that well casing is aligned and plumb within specified tolerances.

F. Field quality-control reports, including the following:
   1. Substrata formations.
   2. Performance test data.

1.04 QUALITY ASSURANCE

A. Well Driller Qualifications: An experienced water supply well driller licensed in the State of Washington.

B. Comply with Washington Administrative Code (WAC) Title 173 for well casing requirements.
C. Qualify welding processes and welder performance in accordance with AWS B2.2 or ASME Boiler and Pressure Vessel Code, Section IX.

1. Certify that each welder has satisfactorily passed AWS or ASME qualification tests for welding processes involved and, if pertinent, has undergone re-certification.

2. Certification of procedures and operators applies for both shop and job site welding of pipe work.

D. Welding procedures shall address cleaning, joint clearance, overlaps, internal purge gas, purge gas flow rate, and filler metal.

1.05 DESCRIPTION OF WELL SITE

A. The Contractor shall drill and install the casing pipe at the location shown on the Contract Drawings.

B. Refer to the Geotechnical Baseline Report.

1.06 PROJECT CONDITIONS

A. Well Drilling Water: Provide temporary water and piping for drilling purposes. Provide necessary piping for water supply.

B. Noise Control: Refer to Section 01 57 16, Temporary Construction Noise and Vibration Control.

C. Allowable Work Times: Refer to Section 01 57 16, Temporary Construction Noise and Vibration Control.

D. Plumbness and Alignment: The completed well and casing shall be drilled in such vertical alignment that a line drawn from the center of the well casing at ground surface to the center of the well casing 150 feet below the ground surface shall not deviate from the vertical more than 6 inches in 100 feet of length.

1.07 PERMITS AND LICENSES

A. The Contractor shall, at his own expense, procure all permits, certificates and licenses required by law for the execution of his work. The Contractor shall comply with all federal, state, and local laws, ordinances, rules, and regulations relating to the performance of the work.

PART 2 - PRODUCTS

2.01 WELL CASINGS

A. Stainless Steel Casing: ASTM A778, 0.25-inch wall, 316L stainless steel pipe, welded joints.

2.02 FORCE MAIN LINER PIPING

A. ASTM A312, Schedule 40, seamless stainless steel, type 304L pipe with ASTM A403, Gr. WP304, butt-weld fittings.
B. Use ASTM A182, Gr. F304, 150 pound flanges with 1/16-inch raised face, serrated face finish and weld neck pattern.

2.03 GROUT

A. Cement: ASTM C150, Type II.
B. Aggregates: ASTM C33, fine and coarse grades.
C. Water: Potable.

2.04 PACK MATERIALS

A. Coarse, uniformly graded filter sand, maximum 1/8 inch in diameter.

PART 3 - EXECUTION

3.01 PREPARATION

3.02 INSTALLATION

A. Take samples of substrata formation at 10-foot intervals and at changes in formation throughout entire depth of the well. Carefully preserve samples on-site in glass jars properly labeled for identification.

B. Rotary Drilled Well: Excavate for mud pit or provide above ground structure, acceptable to Washington State Department of Ecology to allow settlement of cuttings and circulation of drill fluids back to well without discharging to on-site waterways.

C. Enlarge pilot hole and install permanent casing and grout.

D. Set casing and liners round, plumb, and true to line.

E. Join casing pipe as follows:
   1. Ream ends of pipe and remove burrs.
   2. Remove scale, slag, dirt, and debris from inside and outside casing before installation.
   3. Weld joints.

F. Capture and dispose of any drilling fluid that enters the cross passage.

G. Mix grout in proportions of 1 cubic foot or a 94-pound sack of cement with 5 to 6 gallons of water. Bentonite clay may be added in amounts of 3 to 5 pounds per cubic foot for a 94-pound sack of cement. If bentonite clay is added, water may be increased to 6.5 gallons per cubic foot of cement.

H. Perform grouting operation between the casing and force main pipe in two phases. In the first phase, place a suitable temporary sealing material between the casing pipe and the force main pipe to provide a waterproof seal. Place no more than 10 feet of grout in the annulus and allow the grout to harden a minimum of 72 hours. After the initial grout has hardened, fill the remaining annular space in one operation. Care should be taken to monitor that no grout enters the tunnel during initial or final grouting of the annular space. Do not perform other operations in the well within 72 hours after final grouting of the
casing. If quick setting cement is used, the wait period between grouting phases and the final grouting and other operations may be reduced to 24 hours.

3.03 JOINTS

A. Welded Joints: Weld joints between sections of pipe and between pipe and fittings using either gas or electric welding equipment. Stainless steel welding shall conform to ANSI/AWS B2.1.005. All pipe surfaces shall be thoroughly cleaned before welding. Each joint, except socket-weld joints, shall be beveled before being welded. The Contractor shall provide a non-flammable mat or blanket to protect adjacent property and adequate fire protection equipment at all locations where welding is done. All elbows shall be long radius where space conditions allow. The use of fittings formed from welded pipe sections will not be permitted.

3.04 CONNECTIONS

A. Piping Installation: Contract Drawings indicate general arrangement of piping, fittings, and specialties.


3.05 FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:

1. Plumbness and Alignment Testing: Comply with AWWA A100 and the following:

   a. Alignment shall be tested by lowering into the well to a depth of at least 150 feet a 40-foot long section of 8-inch PVC pipe.

C. All piping, equipment, and accessories installed under this Contract shall be inspected and tested by the Contractor in the presence of the Resident Engineer, and approved before acceptance. The Contractor shall furnish all labor, material, and equipment required for testing. The Contractor shall be responsible for all repairs and retesting as required. All instruments and other equipment whose safe pressure range is below that of the test pressure shall be removed from the line or blanked off before applying the tests.

D. Hydrostatic Tests

1. Perform pressure tests for force main piping in accordance with the Field Quality Control requirements in Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

END OF SECTION
SECTION 26 05 00
COMMON WORK RESULTS FOR ELECTRICAL

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes general specifications applicable to Division 26, Electrical, wiring devices, disconnect switches, fuses, and control relays.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 50 00, Temporary Facilities and Controls.
2. Section 01 51 15, Temporary Electrical Power.
3. Section 01 60 00, Product Storage and Handling.
4. Section 01 77 00, Close Out Procedures.
5. Section 01 78 39, Project Record Documents.
6. Division 26, Electrical.

1.02 REFERENCES

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

1. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE C2 National Electrical Safety Code (also an ANSI Standard)

2. International Conference of Building Officials:
   a. International Building Code (IBC)

3. National Electrical Contractors Association
   a. NECA 1 Standard Practices for Good Workmanship in Electrical Construction

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA KS 1 Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
   b. NEMA WD 1 General Requirements for Wiring Devices
   c. NEMA WD 5 Specific-Purpose Wiring Devices
   d. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)
5. National Fire Protection Association (NFPA):
   a. NFPA 70 National Electrical Code
   b. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems
6. Underwriters Laboratories (UL):
   a. UL 198E Class R Fuses
   a. 19.27 RCW Washington State Building Code
   b. 19.28 RCW Electricians and Electrical Installations
   b. 296-46 WAC Safety Standards – Installing Electric Wires and Equipment – Administrative Rules

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. 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.

C. 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 and 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 provided the certification is approved by the authority having jurisdiction.

D. Factory Test and Inspection Certification:
   1. Where factory tests and inspections for materials and equipment specified in referenced documents are waived, provide certified copies of reports for tests
performed on previously manufactured identical materials or equipment within the previous 12 months.

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 Project. Include wiring and control diagrams.

E. 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.

F. Certified Field Test Reports of field tests, verifying compliance of equipment and systems with Specification requirements.

G. Operation and Maintenance Manuals and instructions and data for equipment provided under this Division, in accordance with the requirements of Section 01 78 23, Operation and Maintenance Data. Include recommended maintenance materials and spare parts list for installed equipment.

1.04 QUALITY ASSURANCE

A. Qualifications: Workers performing shall meet the qualification and licensing requirements of Chapter 19.28 RCW (Electricians and Electrical Installations).

B. Perform work in compliance with the following industry standards and regulations.

1. NFPA 70 National Electrical Code.

2. NECA 1, Standard Practices for Good Workmanship in Electrical Construction.


4. State of Washington Business Regulations and Administrative Codes:
   a. Chapter 19.27 RCW
   b. Chapter 19.28 RCW
   c. Chapter 51-40 WAC
   d. Chapter 296-46 WAC

5. Relevant amendments to Washington State regulations and codes adopted by local jurisdictions.


1.05 COORDINATION

A. Coordinate any items that effect any existing University of Washington system with UW facilities department.
PART 2 - PRODUCTS

2.01 MATERIALS

A. General

1. Furnish materials and equipment of design, sizes, and ratings as indicated and 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 are optional unless otherwise indicated.

4. Provide products that are free from defects, which may impair performance, durability, or appearance.

5. For tunnel installation, use materials including exposed raceways, boxes, cabinets, luminaires, equipment enclosures, and their surface finish material which are capable of being subjected to temperatures up to 932 degrees F for 1 hour and do not support combustion as required by NFPA 130.

B. Receptacles

1. Receptacle Standards: Connector and outlet receptacles shall conform to NEMA WD 1, heavy-duty general use type.

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.

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. Ground Fault Circuit Interrupter (GFCI) Receptacles: For ground fault circuit interrupter (GFCI) duplex receptacles use 120 V, 60 Hertz, 20 A with built-in test, reset buttons, and ground fault tripped indication that interrupts the circuit within 1/30 second on a 5 milliampere earth leakage current. Use GFCIs designed for end of run installation or with provisions for feeding through to protect other outlets on a 20 A Circuit. Furnish receptacles with necessary wire connectors, clips, mounting screws, and instructions.

C. Cover Plates

1. Provide multi-gang plates where required. Segmented cover plates are not acceptable.

2. Finished area device covers: brushed, stainless steel, 0.040-inch thickness.

4. For special purpose outlets, provide plates of brushed stainless steel and of a design for the particular application.

5. Weatherproof cover plates: die-cast, copper-free aluminum listed for wet locations with self-closing spring door and rubber gasket. Provide accessories for locking cover with a padlock.

D. Disconnect Switches

1. Provide enclosed, heavy-duty safety switches, conforming to NEMA KS 1.

2. Heavy-duty Safety Switches (600 V AC):
   a. Provide switches having electrical characteristics, ratings, and accessories as required or as indicated. Provide fuse rejection devices either factory-installed or field-installed.
   b. Tunnel, cross-passages and areas exposed to weather: Provide NEMA 250 Type 4X, stainless steel enclosures.
   c. General Locations: Provide NEMA 250 Type 12 industrial duty enclosures.
   d. Provide handle with visible blades; reinforced fuse clips; nonteasible, positive, quick-make, quick-break mechanism; and padlockable in the OFF and ON positions.

E. Individual Control Relays

1. Use control relays which have convertible contacts rated a minimum of 10 A, 600 V. Verify coil voltage, and number and type of contacts. Provide NEMA 250 Type 1 enclosures.

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 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.

F. Electrical equipment: Conform to IBC 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 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. Wiring
   1. Provide wiring systems complete as indicated and required for proper service.
   2. Provide ample slack wire for motor loops, service connections, and extensions.
   3. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.

K. Wiring Devices and Cover 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 and provide with weatherproof cover plate.
   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 in public areas and trainways.
   5. Provide cover plates for each switch, receptacle, and special purpose outlet.
   6. Provide brushed stainless steel cover plates in finished areas.
   7. Provide galvanized steel cover plates in ancillary spaces, mechanical rooms, fan rooms, electrical closets, electrical rooms, traction power substations, and unfinished areas.

3.02 INTERFACE WITH OTHER WORK

A. Coordinate the work of this Section with the other Specification Sections of this Division 26, Electrical, as required to provide a complete and operable electrical installation.

B. Coordinate electrical services and work with the serving utility company and Sound Transit, as applicable.

C. Coordinate with work completed or in progress or to be performed under other Sections of these Specifications or by other contractors. Make indicated connections to previously completed work. Where future connections to or extensions of the work are indicated, provide safe and convenient provisions for such future connections and extensions.

D. Contract Drawings show electrical equipment, ductbanks, raceways, and other electrical facilities diagrammatically and do not show all accessories or fittings that are required.
because of obstructing structural features and architectural finishes, interfering utilities, ducts, and mechanical equipment. Investigate such conditions and determine the need for locating equipment and materials and routing electrical raceways clear of such obstructions and interferences. Provide complete and operable electrical systems and installations in conformance with these Specifications.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 26 05 25
WIRE AND CABLE

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing low voltage copper wires and cables, wiring connections, and terminations. All wires with insulation level 600 V and below which includes power, control, instrumentation, and for grounding purposes are included in this section.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

Section 01 78 23, Operation and Maintenance Data.

Section 26 05 00, Common Work Results for Electrical.

Section 26 05 26, Grounding and Bonding for Electrical Systems.

Section 26 05 33, Raceway and Boxes for Electrical Systems.

Section 26 05 53, Identification for Electrical Systems.

Section 26 08 00, Commissioning of Electrical Systems.

1.02 REFERENCES

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

   a. ASTM B3 Specification for Soft or Annealed Copper Wire
   b. ASTM D1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications
   c. ASTM D1518 Test Method for Thermal Transmittance of Textile Materials
   d. ASTM D3005 Specification for Low-Temperature Resistant Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape
   e. ASTM D5034 Breaking Force and Elongation of Textiles Fabrics (Grab Test)

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE 383 Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations

3. National Electrical Contractors Association
a. NECA 1 Standard Practices for Good Workmanship in Electrical Contracting

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA WC 70 Non-Shielded Power Cable 2000 V or Less

5. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code
   b. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Before installation of wire and cable, submit the following information for each type and size of wire and cable:

1. Manufacturer of wire and cable, and certificate of compliance;
2. Number and size of strands composing each conductor;
3. Average overall diameter of finished wire and cable;
4. Minimum insulation resistance in megohms per 1000 feet at 30 degrees C ambient;
5. Jacket composition and thickness in mils;
6. Total number of conductors per cable;
7. Shield material, if any, and thickness;
8. Conductor resistance and reactance in ohms per 1000 feet at 25 degrees C ambient; and
9. Conductor ampacity at 30 degrees C ambient for 600 volt (V) wire and cable.
10. Conductor overall diameter (OD) and weight per 1000 feet of cable.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Ship each unit securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.

B. Store wire and cable in secure and dry storage facility, in accordance with NECA 1.

1.05 WARRANTY

A. Submit manufacturer’s standard warranty.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Wire and Cable Markings
   1. Verify that wire and cable markings are in accordance with applicable NEMA and National Electrical Code requirements.

B. 600 Volts Single Conductor Cable
   1. Conductor Material: ICEA stranded or solid copper meeting requirements of ASTM B3, soft drawn.
   2. Conductor Type:
      a. No. 12 American Wire Gauge (AWG) and Smaller: Solid conductor.
      b. No. 10 AWG and Larger: Class B stranded.
      c. No. 14 to 1/0 AWG: Type XHHW-2, cross-linked polyethylene insulated in accordance with NEMA WC 70.
      d. No. 2/0 AWG and Larger: Type XHHW-2, cross-linked polyethylene insulated in accordance with NEMA WC 70 or type RHH/RHW, ethylene-propylene-rubber-insulated in accordance with NEMA WC 70.
   3. Temperature Rating: Use cables temperature rated not less than 75 degrees C.
   4. Fire-Retardant Properties:
      a. Power cable for emergency fans and related equipment and all tunnel lighting cables shall meet the flame propagating criteria of IEEE 383, the requirements of NFPA 130, and have a minimum circuit time of five minutes in the flame test of IEEE 383. The listed cable system shall have a minimum 1-hour fire-resistive rating in accordance with UL 2196.
      b. Fire ventilation fans cabling shall meet high temperature rating in accordance with applicable NFPA 130 requirements.
      c. Provide type test certificate for every shipment of cables.
   5. Insulation Rating: 600 V.

C. Multiple Conductor, Low-Voltage Cable
   1. Provide multiple conductor cable conforming to NEMA WC 70, approved for use in cable tray, with the following additional requirements:
      a. Number of Insulated Conductors: As indicated.
      b. Provide multiple conductor cable for all power applications, except receptacles when installed in cable tray for sizes up to No. 4/0 AWG, as indicated.
      c. Insulation: As specified above for single conductor cable.
      d. Overall Covering: Jacket cable over the insulation.
e. Multiple conductor for control wire use minimum of No. 14 AWG stranded copper.

f. Insulation Rating: 600 V.

2. Make multi-conductor cable by assembling individual or twisted pairs of insulated conductors into a tight cylindrical form using fillers that are compatible with other materials in the cable. Use the jacket to fit tightly to form a firm assembly.

D. Fixture Wire

1. Provide fixture wire conforming to the following requirements:

   a. Type: SF-2 silicone rubber insulated.

   b. Conductor: Stranded copper conductor No. 16 AWG or larger as indicated.

E. Bare Conductor

1. Use ASTM B3, Class B stranded, annealed soft-drawn copper conductor unless otherwise indicated. Size as indicated. Use bare conductor for ground wire only and as specified in Section 26 05 26.

F. Color Coding of Conductors (600 V)

1. Identify individual conductors of multi-conductor cables by means of solid colors, stripes, or printing, unless otherwise approved by the Resident Engineer.

   a. Jacket Printing: Use cables which have printing on the jacket or a printed marker tape under the jacket. Verify that jacket printing includes, but is not be limited to, the number of conductors, conductor size, voltage rating, name of manufacturer, manufacturer's type, and date of manufacture; and that this information appears at intervals of not more than 30 inches.

   b. Footage Marker Tape: Provide cables with a footage marker tape under the jacket or hot-foil footage printing on the jacket.

   c. Power Cables: Conform to the following color coding for power cables:

<table>
<thead>
<tr>
<th>Conductor</th>
<th>480Y/277 V</th>
<th>208Y/120 V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A</td>
<td>Brown</td>
<td>Black</td>
</tr>
<tr>
<td>Phase B</td>
<td>Orange</td>
<td>Red</td>
</tr>
<tr>
<td>Phase C</td>
<td>Yellow</td>
<td>Blue</td>
</tr>
<tr>
<td>Neutral</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td>Ground</td>
<td>Green</td>
<td>Green</td>
</tr>
</tbody>
</table>

2. Use solid color insulation or solid color coating for branch circuit phase conductors No. 10 AWG and smaller and all neutral and equipment ground conductors.

3. Use a background color other than white or green for phase conductors with colored tracers.
4. For solid color coatings and tracers, use a strongly adherent paint or dye not injurious to the insulation which will not be obliterated by pulling into a conduit or raceway.

5. Resident Engineer may permit on-site coloring of ends of conductor upon receipt of satisfactory evidence that the Contractor is unable to order color-coded wire and cable as specified. Provide certification from the cable manufacturer that the paint or dye proposed for field application is non-injurious to the insulation.

G. Connectors and Insulating Tapes

1. Splice and Terminal Connectors:
   a. Provide termination fittings listed for use with the cable furnished, NEMA standard.
   b. For termination and splice fittings on No. 10 and smaller conductors use compression type or insulated, expanding-spring type. Make wire splices either self-insulating or provided with an insulating cap or heat-shrink insulating sleeve.
   c. For termination and splice fittings on No. 8 and larger conductors use tool-applied compression connectors of material and design compatible with the conductors for which they are used.
   d. For terminal connectors on conductors size No. 4/0 and larger use long-barrel, double-compression type, and furnish with two NEMA standard bolt holes in the tongue.

2. Insulating Material for Splices and Terminations:
   a. Provide insulating material for splices and terminations of type accepted by the Resident Engineer for the particular use, location, and voltage.
   b. For general use electrical insulating tape use vinyl plastic with rubber based pressure sensitive adhesive, which is pliable from temperatures of minus 18 degrees C to 105 degrees C. Verify the tape has the following minimum properties when tested in accordance with ASTM D3005:
      1) Thickness: 7 mils.
      2) Breaking Strength: 15 pounds per inch.
      3) Elongation: 200 percent.
      4) Dielectric Strength: 10 kV/millimeters.
      5) Insulation Resistance (Direct method of electrolytic corrosion): 10 Mega-ohms
   c. For rubber electrical insulating tape for protective over-wrapping use silicone rubber with a silicone pressure-sensitive adhesive. Verify the tape has the following minimum properties when tested in accordance with ASTM D1000:
      1) Elongation: 525 percent.
      2) Dielectric Strength: 13 kilovolts (kV).
3) Insulation Resistance (Indirect Method of Electrolytic Corrosion):
10 (Mega-ohms)

H. Conductor Bundling Straps
1. Provide conductor bundling straps formed from self-extinguishing nylon having a
   temperature range of negative 40 degrees F to 185 degrees F.
2. Equip each strap with a locking hub or head with a stainless steel locking barb on
   one end and a taper on the other end.
3. Ensure all wire and cable ties installed outdoors and in exposed locations are
   made of ultraviolet-resistant material.

PART 3 - EXECUTION

3.01 INSTALLATION
A. Coordinate installation of wires and cables with the requirements of Section 26 05 00
   Common Work Results for Electrical, Section 26 05 33 Raceway and Boxes for Electrical
   Systems, Section 26 05 26 Grounding and Bonding for Electrical Systems and Section 26
   05 53 Identification for Electrical Systems.
B. Furnish wires and cables to the site in unbroken standard coils or reels upon which a tag
   is attached bearing the manufacturer’s name, trade name of the wire, and listing
   information.
C. Complete wiring as indicated. Provide ample slack for field terminated wires and
   preformed cables with connections, including wires for motor loops, service connections,
   and extensions. In outlet or junction boxes provided for installation of equipment by
   others, tape ends of wires and install blank covers.
D. Do not bend cables during installation, either permanently or temporarily, to radii less
   than twelve times the outer diameters, except where conditions make the specified radius
   impractical and shorter radii are permitted by the manufacturer.
E. Bundle cable and conductors neatly and securely with nylon straps in branch circuit
   panelboards, cabinets, control boards, and motor control centers. Bundle power cables
   separately from control cables.
F. Install motor feeders, service connections, and extensions in accordance with the
   referenced codes. Install motor feeder in liquid-tight flexible conduit of 18 inches
   minimum length at motor conduit box.
G. For wire pulling, comply with NECA 1 and the following:
   1. Install wire and cable in conduit as indicated. Do not use block and tackle or
      other mechanical means for pulling conductors smaller than No. 2 AWG in
      raceways.
   2. Provide suitable installation equipment to prevent cutting and abrasion of
      conduits and wire during the pulling of feeders. Use lubricant and installation
      procedure as recommended by the cable manufacturer.
   3. Do not exceed the manufacturer's recommended pulling tension. For conduit
      runs with three bends, and cable sized larger than No. 2 AWG, provide cable
tension measuring equipment and record the highest cable tension. Notify Resident Engineer 48 hours prior to such pulling operations and adjust schedule as necessary to permit observation.

4. Provide masking or other means to prevent obliteration of cable identifications when solid color coating or colored tracers are used.

H. Power and Control Cable Installation in Manholes and Pullboxes: Route cables along the manhole or handhole walls providing the longest possible slack. Form cables closely parallel to the walls. Prevent cable interference with duct entrances, and support cables on brackets and cable insulators, spaced at a maximum of 4 feet. In existing manholes and handholes where new ducts are to be terminated or where new cables are to be installed, modify the existing locations of cables, cable supports, and grounding as required to provide a properly arranged and supported installation. Ensure minimum bending radius of the cables is not exceeded inside the manholes. Allow sufficient cable coil length based upon the design requirements. Perform dielectric test before performing continuity test. Provide cable identification markers inside the manholes and pull boxes when there are more than one circuit cables routed thru manholes and pull boxes.

I. Splices and Terminations:

1. Make wire and cable splices only in outlet, junction or pull boxes, or in equipment cabinets. Splice in multi-conductor cables in accordance with the cable and splice-kit manufacturers’ recommendations. Insulate splices to a level equal to that of the cable.

2. Use splice and terminator installation tools and installation techniques recommended by the manufacturer.

3. For conductor sizes through No. 6 AWG, use mechanical hand tools, with dies as recommended by the manufacturer.

4. For conductor sizes larger than No.6 AWG, use hydraulic tools with hexagonal or circumferential dies as recommended by the manufacturer.

5. Use compression tools which permanently imprint die information on the completed connection.

6. Use continuous lengths of wire and cable between power source and equipment. Where splices are required, make them only in approved fittings or junction boxes. Splices are subject to approval by the Resident Engineer. Follow manufacturer’s instructions in splicing wire and cable.

7. Fixture Wire: Make splices in lighting circuits with insulated crimp-type connectors.

8. Control Cables: Terminate each wire held with screw-type terminals using an insulated sleeve (nylon), ring-tongue-type or locking spade-type, crimp-on lugs.

3.02 FIELD QUALITY CONTROL

A. Inspect wire and cable for physical damage and proper connections.

B. Perform continuity test on power and equipment branch circuit conductors. Perform dielectric test before performing continuity test on all circuits after installation.

C. Verify phasing for circuits to three-phase loads.
D. Test for insulation resistance in accordance with Section 26 08 00, Commissioning of Electrical Systems.

1. Test after splices and terminations are complete. Do not connect equipment to the cable system during tests.

2. Acceptance Criteria for 600 V wire and cable: 10,000,000 ohms

3. Test Failure: In case insulation resistance values are unacceptable, correct deficiency and retest. If the test fails again, replace the entire wire or cable segment.

END OF SECTION
SECTION 26 05 26
GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for power system grounding, electrical equipment and raceway grounding and bonding, and bonding of metallic objects near the trackway.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common Work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 33, Raceway and Boxes for Electrical Systems.
4. Section 26 08 00, Commissioning of Electrical Systems.
5. Section 26 24 16, Panelboards.
7. Section 26 29 13, Enclosed Controllers and MCC.
8. Section 26 51 14, Lighting Systems

1.02 REFERENCES

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

   a. ASTM B3 Specification for Soft or Annealed Copper Wire
   b. ASTM B187 Specification for Copper Bar, Bus Bar, Rod and Shapes

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE 837 Qualifying Permanent Connections Used in Substation Grounding

3. Underwriters Laboratories Inc. (UL):
   a. UL467 Grounding and Bonding Equipment

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Shop Drawings: Where grounding system is not detailed on the Contract Drawings, submit shop drawings showing locations of ground rods, grounding connections, locations of embedded and buried grounding conductors and locations of stub outs and pigtailed for future connections to the grounding system by others. Indicate on drawings the locations of test points to measure grounding resistance.

C. Manufacturers’ product data of grounding materials and coal-tar epoxy protective coating.

1.04 QUALITY ASSURANCE

A. Provide training for electricians involved in the selection, maintenance and operation of exothermic welding materials and equipment.

B. Resistance testing shall be performed by personnel trained in grounding system installation and testing.

1.05 DELIVERY, STORAGE AND HANDLING

A. Ship each item of equipment and materials securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage.

B. Store equipment and materials in secure and dry storage facility.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Ground Rods: Medium carbon steel core, copper-clad by the molten weld casting process, size of 3/4-inch diameter by 10 feet long or as indicated.

B. Bare Conductors: ASTM B3, Class B stranded, annealed copper conductor, unless otherwise indicated, size as indicated. Refer to Section 26 05 25 Wire and Cable.

C. Bus Bar: ASTM B187, 98 percent conductivity copper, size as indicated.

D. Single Conductor Insulated Wire: Refer to Section 26 05 25, Wire and Cable.

E. Terminal Lugs: Exothermically-welded or compression-type approved for the application.

F. Jumpers: Tin-plated copper, braided, flexible jumper.

G. Exothermic Welding System: Provide dual-component exothermic welding system with molds and accessories of a single manufacturer. Erico, Thermoweld, or approved equal.

H. Compression Connections: Provide connectors and compression tools from a single manufacturer. Use Connectors which have an inspection port for checking proper conductor insertion.

I. Compression Tools: For field quality control, use compression tools that emboss the die index number into the connector as the crimp is completed.

J. Coal Tar Epoxy Coating: Coal tar polyamide epoxy, high-build corrosion resistant coating. Tnemec Series 46H-413, High-build Tnemec-Tar or approved equal.
K. Provide markings on grounding wire, cable, and other grounding components in accordance with applicable standards. Each item shall be UL-Labeled where applicable.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate installation of grounding and bonding with the requirements of Section 26 05 00 Common Work Results for Electrical Systems, Section 26 05 25 Wire and Cable, Section 26 05 33 Raceway and Boxes for Electrical Systems, Section 26 05 53 Identification for Electrical Systems, Section 26 24 16 Panelboards, Section 26 24 13 Enclosed Controllers and MCC and 26 51 14 Lighting Systems.

B. Ground Connections:

1. Buried or embedded connections: Exothermically welded or compression-type terminal lugs using materials qualified in accordance with IEEE 837. Do not bury or embed bolted connections.

2. Exposed connections: Exothermically welded or compression-type terminal lugs using materials qualified in accordance with IEEE 837. Make connections in accordance with the manufacturer's instructions. Bolted connections are permitted only in secured locations not accessible to the public.

3. Make connections in accordance with the manufacturer's requirements. Clean ferrous structures and piping and coat with a coal-tar epoxy for a distance of 6 inches from the grounding attachment point.

4. Do not bond buried metallic piping systems or structures to grounding electrode systems unless specifically directed.

5. Provide continuous ground conductor or splice using connections qualified in accordance with IEEE 837.

6. For connections from a grounding bus to grounding electrode system, provide a ground lug fastened with stainless steel bolts and locking hardware. Provide exothermically-welded or compression lug on grounding electrode conductor.

7. Provide waterstops on stranded, ground conductors where they enter a structure.

C. Ground Rods:

1. Bury ground rods vertically with top of rod a minimum of 12 inches below grade or as indicated. If extensive rock formation is encountered, relocate ground rods to a new location as approved by the Resident Engineer.

2. Interconnect ground rods with minimum No. 1 AWG stranded, bare copper cable or as indicated.

D. Station Electrical System Grounding Electrode

1. Provide ground ring with multiple ground rods or concrete-encased grounding electrode system. Unless otherwise indicated, bury conductors of the grounding ring in native fill not less than 36 inches below final grade.
2. Provide minimum No. 1 AWG stranded, bare copper conductor for grounding ring and concrete-encased electrode.

3. Measure grounding electrode resistance of the installed system and provide additional bonded ground rods as necessary to meet the maximum acceptable ground resistance as specified herein.

E. Communications and Train Control System Grounding Electrode

1. Provide two ground rods separated by 8 feet and bonded to communications and train control systems cabinets and bond to electrical system grounding electrode with number six insulated copper conductor. Isolated connections to structure reinforcing/ concrete-encased grounding electrode system are also acceptable.

2. Measure grounding electrode resistance of the installed system and add additional bonded ground rods as necessary to meet the maximum acceptable ground resistance as specified herein.

F. Equipment Grounding Requirements

1. Install insulated copper equipment-grounding conductor with phase conductors in each raceway and bond to metallic raceways and boxes at access and pull points.

2. Size equipment grounding conductors in accordance with the National Electrical Code to provide adequate conduction path for ground faults. Increase size as required to allow for circuit voltage drop.

3. Ground metallic raceways, boxes, cabinets, exposed expansion joints, lighting fixtures, motors, transformers, MCC and receptacles. Provide grounding bushings or compression connectors attached with machine screws for bonding.

G. Facility and Tunnel Bonding Requirements: Bond metallic objects within 15 feet of the track centerline to the station grounding electrode. This includes but is not limited to station and tunnel structures, equipment cabinets, handrails, fences, bollards, cable or chain barriers, and art objects. Do not make bonding connections below or above ground at an inconspicuous location on the object. Protect exposed connections and grounding conductor from damage and theft. Bond continuous metallic objects, such as fences, at a minimum, every 30 feet.

H. Trackway Bonding Requirements: Bond reinforced concrete rebar embedded in separate sections of the tunnel segments by grounding jumpers as indicated in systems grounding plan. Track rails shall not be used for temporary or permanent grounding

3.02 FIELD QUALITY CONTROL

A. Test the installed grounding system in accordance with Section 26 08 00, Commissioning of Electrical Systems

B. Acceptance Criteria:

1. Station Grounding System: 10 ohms, maximum.

2. Equipment Grounding: Not to exceed 5 ohms

3. Communications and Train Control System Grounding Electrode: 5 ohms, maximum.
4. Traction Power Substation or Tie Station Grounding Electrode: 5 ohms, maximum.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing electrical raceways including conduit, ducts, outlet, junction and pull boxes, manholes, hand-holes and electrical cabinets.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common Work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 26, Grounding and Bonding for Electrical Systems.
4. Section 26 05 43, Underground Ducts and Raceways for Electrical Systems.
5. Section 26 05 53, Identification for Electrical 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 C80.1 Rigid Steel Conduit - Zinc Coated

   b. ASTM A153/A153M Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

3. National Electrical Contractors Association (NECA)
   a. NECA 1 Standard Practices for Good Workmanship in Electrical Contracting

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA RN1 Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
   b. NEMA TC2 Electrical Polyvinyl Chloride (PVC) Tubing and Conduit
   c. NEMA TC3 PVC Fittings for Use with Rigid PVC Conduit and Tubing
d. NEMA TC6 & 8 PBC Plastic Utilities Duct for Underground Installations

e. NEMA TC14 Reinforced Thermosetting Resin Conduit (RTRC) and Fittings

f. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

5. National Fire Protection Association (NFPA):

a. NFPA 70 National Electrical Code

b. NFPA 130 Fixed Guideway Transit and Passenger Rail Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. List of Materials: Submit a list of materials 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.

C. Compliance with Applicable Standards:

1. Where equipment or materials are specified to conform to the standards of organizations such as NFPA, NECA, ANSI, ASTM and NEMA, submit evidence of conformance. The label or listing of the specified agency will be acceptable evidence.

2. Instead of the label or listing, the Contractor can also submit a written certificate from an approved, nationally recognized testing organization, stating that the items have been tested and that the units conform to the specified standard.

D. Shop Drawings:

1. Showing the exact location and arrangement of conduits, cabinets, and pullboxes installed under this Contract.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Conduit and Duct

1. Galvanized Rigid Steel (GRS) Conduit and Accessories: ANSI C80.1; hot-dip galvanized inside and out after threading; ensure each length bears UL label.

   a. Fittings and Accessories:

      1) Bushings: Nylon-insulated, metallic, grounding type.

      2) Conduit straps, clamps, and clamp backs: Galvanized malleable iron.

      3) Conduit Seals: Suitable for Class 1, Division 2, Group D hazard location.
4) Conduit Outlet Bodies: Feraloy iron alloy electrogalvanized with aluminum acrylic paint or approved equal.

2. PVC-Coated GRS Conduit (PVC/GRS or PGRSC): NEMA RN1, with corrosion resistant internal coating.

3. Shipping: Thread protectors installed on both ends of conduit, with couplings packaged separately.

4. PVC Electrical Conduit and Fittings: NEMA TC2, EPC-40-PVC; heavy wall, high impact strength, rigid PVC.
   a. Fittings: NEM TC3, EPCA-40-PVC.

5. Plastic Utilities Duct: NEMA TC6 & 8, Schedule 20 type EB.

6. Epoxy and Phenolic Fiberglass Conduit and Fittings: NEMA TC14; standard-wall
   a. Conduit joints and fittings: Tapered or untapered; all of one type.

7. Innerduct
   a. Premanufactured multi-cell raceway assembly:
      1) Four 1.25-inch inside-diameter, pre-lubricated PVC innerducts pre-installed in each 4-inch, 10 or 20-foot outer ducts. Verify that Individual innerducts meet the requirements for separate innerduct raceways below.
      2) Manufacturer’s standard product including necessary spacers, couplers and pre-manufactured ells.
      3) Acceptable manufacturer: Carlon Multi-Gard or approved equal.
   b. Separate innerduct raceways
      1) 1-inch inside diameter smooth- or longitudinal-ribbed-wall, flexible PVC or polyethylene tubing with 0.125-inch wall thickness.
      2) Suitable for pulling into conduit and provided with fittings necessary to make up a complete raceway system.
      3) Acceptable manufacturer: Carlon, Pyramid or approved equal.

8. Liquidtight Flexible Metallic Conduit and Fittings:
   a. Core: Flexible galvanized steel with a continuous copper bonding conductor spiral wound between the convolutions.
   b. Jacket: Extruded liquid-tight plastic or neoprene; moisture- and oil-proof, capable of conforming to the minimum radius bends of flexible conduit without cracking; self-extinguishing with low halogen containing material.
   c. Fittings: Zinc-coated.

9. Conduit Expansion Fittings:
a. Factory installed packing ring, designed to prevent the entrance of moisture.

b. Pressure ring.

c. Grounding ring or a grounding conductor for metallic expansion couplings.

d. Use fittings which maintain a constant inside diameter in every position and provide a smooth wireway for protection of wire insulation.

B. Galvanized Steel Field Coating

1. Organic cold galvanizing coating: minimum 95 percent metallic zinc by weight in dried film; manufactured by ZRC Products Company, or approved equal.

C. Oxide inhibiting joint compounds

1. Petroleum-based compound with evenly suspended zinc particles.

2. Burndy, Penetrox A, or approved equal.

D. Conduit Trapeze Hangers and Framing Channel

1. Hangers:
   a. Two or more steel hanger rods, a steel horizontal member, U-bolts, clamps, and other attachments as necessary for securing hanger rods, and conduits.

   b. Capable of supporting a load equal to the sum of the weights of the conduits and wires, the weight of the hanger itself, plus 200 pounds

2. Steel hanger rods: Galvanized, not smaller than 3/8-inch diameter, threaded either full length or for a sufficient distance at each end to permit at least 1-1/2 inches of adjustment

3. Horizontal member:
   a. Structural grade steel, 1-1/2 by 1-1/2 inches or 1-5/8 by 1-5/8 inches, 12 gage, cold-formed, lipped channel, designed to accept special spring-held hardened steel nuts for securing hanger rods and other attachments. Ensure nuts and clamps are compatible with the channel.

   b. Weld together two or more channels to form horizontal members of greater strength.

   c. Hot-dip galvanized after fabrication in accordance with ASTM A123/A123M or ASTM A153/A153M, as applicable.

   d. Manufacturer: Unistrut, Allied Tube and Conduit or approved equal.

E. Wireways

1. Type 4X stainless steel feed-through wireways.

2. Covers and bodies: 16 gauge type 304 stainless steel.

3. Flanges: 10 gauge stainless steel.
4. Seems continuously welded and ground smooth, no holes or knockouts.

5. Oil resistant gaskets and adhesives.

6. Manufacturer: Hoffman or approved equal.

F. Outlet Boxes; Junction and Pull Boxes

1. Provide electrical boxes of the material, finish, type, and size indicated and as required for the location, kind of service, number of wires, and function. For boxes located in tunnels and cross-passages use NEMA 4X stainless steel unless otherwise approved.

2. Provide boxes complete with accessible covers designed for quick removal and suitable for the purpose for which they will be used.

3. Equip boxes in which, or on which, no devices or fixtures are to be installed with flat or raised blank covers as required.

4. For boxes below 100 cubic inches in size or boxes for embedment in concrete use cast metal. Conform to the requirements for cabinets for boxes over 100 cubic inches in size, except when boxes in interface pull boxes are cast metal with gasketed cast metal covers. Use Type FD boxes for surface mounted wiring devices.

5. Ensure covers are the same thickness as boxes and are secured in position by means of No. 10-24 stainless steel machine screws. Arrange covers to be readily and conveniently removed.

6. Ensure Junction boxes are galvanized inside and outside. Where outlet boxes are used as junction boxes, do not use boxes smaller than 4 inches square by 1-1/2 inches deep. Provide such boxes with flat blank covers.

7. For exposed installation, use outlet and switch boxes made of cast metal, not smaller than 4 inches square by 2-1/8 inches deep.

8. Provide brackets, supports, hangers, fittings, bonding jumpers, and other installation accessories as required.

9. Provide neoprene gaskets 1/8-inch thick for boxes subjected to weather.

10. Ground each box as specified in Section 26 05 26, Grounding and Bonding for Electrical Systems.

11. Ensure boxes for systems control and communications applications conform to NEMA 250 Type 4 and provided with NEMA Type 4 labels.

12. Provide conduit outlet bodies mogul type.

G. Electrical Cabinets and Boxes to be NEMA 4X or as indicated.

1. Cabinet Boxes: Galvanized or stainless steel, size as noted on Contract Drawings. Provide white, galvanized steel interior mounting panel for mounting terminal blocks and relays in interface terminal cabinets.

2. Cabinet Fronts: Steel, surface or recessed type as required for the application with continuous hinge and flush lock. Supply locks for cabinets from a single manufacturer with standard key blank that are field-keyable.
3.

Electrical Service and Distribution Cabinets: Stainless steel with non-directional brushed finish and accessories shown on Contract Drawings. Provide metering provisions meeting the requirements of the serving electric utility for Service Cabinets. Provide lock mechanism as required above.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Coordinate installation of raceways and boxes with the requirements of Section 26 05 00 Common Work Results for Electrical, Section 26 05 25 Wire and Cable, Section 26 05 26 Grounding and Bonding for Electrical Systems, 26 05 26 Grounding and Bonding for Electrical Systems and Section 26 05 43 Underground Ducts and Raceways for Electrical Systems, Section 26 05 53 Identification for Electrical Systems.

B. General Requirements

1. Install electrical raceway, boxes and accessories in locations as indicated, in accordance with NFPA 70, NFPA 130, and NECA 1, to provide a complete and operable system.

2. Ensure conduit, support fittings, boxes and conduit fittings are of compatible materials that will not corrode when subjected to moisture or standing water.

3. Provide anchor bolts and anchorage items as required, and field check to ensure proper alignment and location.

4. Install conduit so as to avoid conflicts with other work. Install horizontal raceways close to the ceiling or ceiling beams and above water or other piping wherever possible.

C. Conduit and Duct Type Requirements

1. Above grade exterior or potentially-wet areas: GRS or fiberglass conduit.

2. Below grade interior spaces (tunnels, cross passages, shafts, and stations):
   a. Embedded conduit - PVC conduit and accessories.
   b. Exposed conduit – GRS conduit and accessories.

3. Conduits for emergency loads (such as emergency lighting and fire alarm system): GRS or PVC/GRS.

4. Below grade exterior areas: PVC/GRS conduit, PVC electrical conduit encased in concrete ductbanks, fiberglass conduit, or plastic utility duct encased in concrete ductbanks.

5. Install PVC electrical conduit only when it will be embedded in slabs and walls or where required in short sections for electrical isolation. Do not leave PVC conduit exposed unless specifically shown on Contract Drawings. Terminate PVC within concrete walls or slabs with a male adapter and PVC/GRS coupling installed flush with the finished surface.

6. Provide PVC/GRS conduit section for transition between an embedded conduit and the above-ground metallic conduit. Ensure that the above-ground PVC-
coated metallic conduit extends 1 foot minimum above ground or to box termination, whichever is less.

7. Install liquid tight flexible metal conduit only where required for flexibility such as connections to vibrating equipment and across joints subject to differential movement.

8. Do not use running thread.

D. Conduit Minimum Sizes

1. GRS: 3/4-inch diameter for exposed locations and 1-inch diameter for embedded locations.

2. PVC/GRS: 3/4-inch diameter for exposed locations and 1-inch diameter for embedded locations.

3. PVC Conduit: 3/4-inch diameter for exposed locations, 1-inch diameter for embedded locations.

4. EB Duct: 4-inch diameter.

5. Fiberglass Conduit: 3/4-inch diameter for exposed locations and 1-inch diameter for embedded locations.


7. Liquidtight Metallic Flexible Conduit: 1/2-inch diameter.

E. Conduit and Duct Bends

1. Install conduit runs with not more than 270 degrees total bends between pull boxes. Where more bends are required in a particular run, install pull boxes as required to facilitate pulling conductors even if not indicated.

2. Minimum Bending Radius Within Structures: In accordance with NEC Table 2, Chapter 9.
   a. PVC Conduit Bending Restrictions
   b. Hot bend bends with radii less than 100 feet using a heater recommended by the conduit manufacturer. Bends with radius 100 feet or larger be cold bent.
   c. Do not bend PVC conduit used in ductbanks with a radius less than 6 feet.

3. Minimum Bend Radius Underground
   a. 1-inch conduit: 18-inch radius
   b. 1-1/4-inch conduit: 20-inch radius
   c. 1-1/2-inch conduit: 22-inch radius
   d. 2-inch conduit: 27-inch radius
   e. 2-1/2-inch conduit: 30-inch radius
f. 3-inch conduit: 30-inch radius

g. 3-1/2-inch conduit: 33-inch radius

h. 4-inch conduit: 36-inch radius

i. 5-inch conduit: 42-inch radius

4. EB Duct Bending Restrictions

a. Do not hot bend Type EB duct.

b. Type EB duct can be cold bent for slight offsets or changes in direction. Do not cold bend EB duct for radii less than 120 feet.

F. Conduit and Duct installation

1. Install conduit in accordance with NFPA 130, local codes and ordinances and as indicated.

2. Prevent material and water from entering the conduit, or pull and junction boxes. Provide threaded cap or similar closure designed for the purpose on conduits that are not terminated immediately. Tape is not acceptable for temporary sealing.

3. Match extensions to existing work to existing size.

4. Where conduit passes across an expansion or contraction joint in the structure, install the conduit at right angles to the joint, and provide liquid tight flexible metal conduit or an approved conduit expansion/deflection fitting at the joint.

5. Provide expansion fittings in conduit runs where required to compensate for thermal expansion.

6. Where conduit is exposed to different temperatures, seal the conduit to prevent condensation and passage of air from one area to the other.

7. If PVC conduit or type EB duct is not fully encased at one time, leave one end of the raceway free until encasing is restarted, or a PVC expansion joint is installed in the run.

8. When field threading of conduit is required, clean threads with a solvent to remove oil as recommended by coating manufacturer, and coat threads with organic cold galvanizing coating, in accordance with manufacturer’s instructions.

9. Coat threads with oxide inhibiting compound for metal-to-metal threaded joints. Take care that compound is not present on interior of conduit after installation.

10. Seal conduits with watertight duct sealing system, where waterproofing is required.

11. Install liquid tight flexible metal conduit so that liquids tend to run off the surface and are not drain toward fittings. Provide sufficient slack to reduce the effects of vibration.

12. Terminated stubbed conduits for future in a male pipe plug with provisions for pulling cord attachment. Install wrench-tight into the flush coupling.
13. Seal all conduit penetrations with approved 2-Hr. fire stop material between cross passage and tunnel.

14. Seal all conduit penetrations between sump pump pit and unclassified area.

G. Conduit Grounding And Bonding

1. Install metallic conduits to be electrically and mechanically continuous and connected to ground by bonding to the grounding system.

2. In dry areas, provide two locknuts, one inside and one outside of box or enclosure, for rigid conduit terminating at steel box, panelboard, cabinet, or similar enclosure. In exposed areas and damp and wet locations provide threaded hubs with sealing o-rings at conduit terminations.

3. Terminate the conduit in appropriate boxes at motors, switches, outlets, and junction points.

4. See Section 26 05 26, Grounding and Bonding for Electrical Systems, for requirements.

H. Raceway Support

1. Support individual wall mounted horizontal conduits not larger than 1 inch in diameter by means of one-hole conduit straps with back spacers or individual conduit hangers.

2. Space conduits installed against concrete surfaces 1/4 inch away from the surface by clamp backs or other approved means.

3. Support individual horizontal conduits larger than 1 inch in diameter by individual hangers and forged steel conduit strap for vertical runs.

4. Conduit Hangers:

   a. Support parallel conduits at the same elevation on multiple conduit hangers or channel inserts. Secure each conduit to the hanger or channel insert member by U-bolt, one-hole strap, or other specially designed and approved fastener suitable for use with the hangers or channel inserts.

   b. Support conduit using conduit hangers anchored to the structure. Verify suitability of structure for anchoring with Resident Engineer.

5. Apply cold galvanizing coating to the field-cut ends of steel hanger rods and steel channel.

6. Support rigid metal conduit in accordance with Table 344.30( R))(2) of the National Electrical Code.

7. Support rigid non-metallic conduits in accordance with Table 352.30( R) of the National Electric Code.

I. Outlet, Junction, and Pull Boxes

1. Securely attach outlet, junction, and pull boxes to the structure. Do not use conduits entering the box as supports for the box.
2. Mount outlet, junction, and pull boxes so as to prevent moisture from entering or accumulating within the boxes.

3. Junction and Pull Boxes:
   a. Install so that covers are readily accessible after completion of the installation.

   END OF SECTION
SECTION 26 05 53
IDENTIFICATION FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing electrical equipment nameplates, wire and cable markers, and conduit color coding.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 09 90 00, Painting and Coating.
2. Section 26 05 00, Common Work Results for Electrical.
3. Section 26 05 25, Wire and Cable
4. Section 26 05 33, Raceways and Boxes for Electrical Systems.
5. Section 26 24 16, Panelboards.
6. Section 26 29 13, Enclosed Controllers and MCC

1.02 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Manufacturer’s product data for mounting adhesive.

C. Schedule for nameplates.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Nameplates: Engraved three-layer melamine laminated plastic, not less than 3/32-inch thick, black letters on a white background.

B. Wire and Cable Markers:

1. Non-fading, plastic, printed sleeve labels.

2. Non-fading, plastic, printed cable tag with holes for attachment to cable with plastic cable ties.

C. Mounting Screws: Stainless steel machine screws.

D. Mounting Adhesive: Permanent.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate identification for electrical systems with the requirements of Section 26 05 00, Common Work Results for Electrical, Section 26 05 25, Wire and Cable, Section 26 05 33, Raceway and Boxes for Electrical Systems, Section 26 24 16, Panelboards, Section 26 29 13, Enclosed Controllers and MCC.

B. Degrease and clean surfaces to receive nameplates.

C. Install nameplates parallel to equipment lines.

D. Secure nameplates to equipment fronts using screws or adhesive. Secure nameplate to inside face of recessed panelboard or cabinet doors in finished locations.

E. Conduit Color Coding

1. Coordinate color of paint with Section 09 90 00, Painting and Coating, to identify conduit by system.

2. Low-voltage Distribution System: Unpainted or black

3. Fire Alarm System: Red

3.02 IDENTIFICATION SCHEDULE

A. Conductors: Provide sleeve wire markers on each conductor in panelboard, gutters, pull boxes, manholes, and at load connection. In gutters, pull boxes, and manholes, if cables are not spliced, use a cable tag. Attach tag securely to cable with plastic cable tie.

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.

B. Provide nameplates of minimum letter height as scheduled below.

1. Panelboards, Uninterruptible Power Supplies, Motor Control Centers, Lighting Controllers: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating and source.

2. Disconnect Switches: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating, source, and load served.


4. Motor Starters in Motor Control Centers: 1/4 inch; identify circuit and load served, including location.


6. Transformers: 3/8 inch; identify equipment designation. 1/4 inch; identify primary and secondary voltages, primary source, and secondary load and location.
7. Devices: 1/4 inch; identify device. These devices may be the devices included in the assembly of the equipment such as MCC and may be standard of the manufacturing company, in which case, manufacturer will submit his standard devices nameplate for approval by the resident engineer for deviation from this specification.

a. Control devices
b. Pushbutton stations
c. Selector switches
d. Hand-off-Auto switches

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for test requirements for each type of power distribution equipment before equipment is ready for commissioning. It includes visual inspection of installed equipment; electrical tests for grounding, high-pot (dielectric tests), continuity tests of wiring, and testing of equipment control schematics using step by step procedure of testing the control logic to ensure equipment control system works as designed. Each piece of electrical equipment requires specific tests; which may have been performed by the installation contractor as part of installation work; however, during commissioning, a separate list is made to perform all tests as pre-commissioning work described in this Section.

1.02 REFERENCES

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

1. InterNational Electrical Testing Association (NETA)
   a. Acceptance Testing Specifications for Electric Power Distribution Equipment and Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Details of proposed test equipment and testing procedure.

C. Test Reports

PART 2 - PRODUCTS

2.01 MATERIALS

A. Electrical Megohmmeter for Insulation Testing:

1. 1000 volts(V) Direct Current(dc) output voltage suitable for resistance measurement from 500 kilohm to 500,000 megohms. Use a megohmmeter with an internal bleeder resistor for discharge.

2. Approved Manufacturer: Hipotronics or approved equal.

3. Thermographic equipment NETA Table 100.18 for testing loose connections.

B. High-Potential Test Set:
1. Portable high-potential dc test set, 0 to 130 kilovolts (kV) dc, 10 milliamperes (mA), with regulated output.

2. Internal shorting solenoid and discharge resistor.

3. Two percent full-scale accuracy capable of measuring cable insulation resistance up to 5,000,000 megohms.

4. Approved Manufacturer: Hipotronics or approved equal.

C. Ground Resistance Tester:

1. Three-terminal ground resistance tester with direct reading display.

2. Approved Manufacturer: Biddle (by AVO International) or approved equal.

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL


B. Low Voltage Circuit Breakers, Lighting Panel boards, Lighting fixtures, and MCC

1. Inspect physical and mechanical condition

2. Inspect anchorage, alignment, and grounding

3. Verify that all maintenance devices are available for servicing and operating the breaker

4. Verify the unit is clean

5. Inspect moving and stationary contacts for condition, wear, and alignment

6. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism in accordance with manufacturer’s published data.

7. Inspect bolted electrical connections for high resistance using one of the following methods:
   a. Use of low-resistance ohmmeter.
   b. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer’s published data or NETA Table 100.12.
   c. Perform thermo graphic survey if needed.

8. Verify cubicle fit and element alignment

9. Verify operation mechanism

10. Lubrication requirements if applicable
   a. Verify appropriate lubrication on moving current-carrying parts
b. Verify appropriate lubrication on moving and sliding surfaces

C. Perform integrated testing of electrical mechanical equipment (tunnel sump pumps)
   1. Verify control circuit for pump motor functions properly and PLC is programmed to control the pump operation and remote indication at BMS.
   2. Use temporary pumps for test purposes. If temporary pumps are not available then demonstrate by using contact closure that pumps turn on and off by simultaneous level controller via PLC.

D. Ground Resistance:
   1. Test the grounding system by the fall-of-potential method under the observation of the Resident Engineer. Unless otherwise indicated, demonstrate that total ground resistance does not exceed the required grounding resistance.
   2. Ground System Continuity: Test equipment enclosures, conduit, raceways, exposed expansion joints, lighting fixtures, receptacles, equipment enclosures, wiring system, and other bonded equipment for continuity to the ground system.

E. Test low voltage, 600V maximum cables in accordance with NETA Section 7.3.1.

F. Test molded case circuit breakers in accordance with NETA Section 7.6.1.1

G. Test mini power center transformers in accordance with NETA section 7.2.1.1.

H. Test motor control in accordance with NETA Section 7.16.1.1.

I. Verify by testing the operability of all lighting, lighting fixtures and controls and receptacle circuits.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing enclosed circuit breakers, circuit breaker panelboards and mini power centers.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 26, Grounding and Bonding for Electrical Systems.
4. Section 26 05 33, Raceway and Boxes for Electrical Systems.
5. Section 26 05 53, Identification for Electrical Systems.
6. Section 26 08 00, Commissioning of Electrical 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 C89.2 Dry-Type Transformers for General Applications

   a. ASTM A653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM B187 Specification for Copper Bar, Bus Bar, Rod and Shapes

3. National Electrical Manufacturers Association (NEMA):
   a. NEMA PB1 Panelboards
   b. NEMA AB-1 Molded Case Circuit Breakers and Molded Case Switches
   c. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)
   d. NEMA ST20 Dry-Type Transformers for General Applications

a. NFPA 70 National Electrical Code

5. Underwriters Laboratories (UL):
   a. UL 67 Panelboards

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Manufacturers' product data for specified equipment and materials. Include the following information for each item:
   1. Manufacturer's model number or item identification;
   2. UL listing and rating;
   3. Critical dimensions and mounting arrangement; and
   4. Replacement parts list.

C. Shop Drawings and electrical diagrams as follows:
   1. Panelboards and Mini Power Center:
      a. Show general arrangement, location, and identification of the enclosure.
      b. Identify each circuit.
      c. Show location and identification of terminals,
      d. Show location of barriers.
      e. Provide wiring diagrams.
      f. Enclosures: Show materials and methods of construction, door arrangement, conduit hubs, and knockout locations.
      g. Transformer:
         1) Transformer ratings including:
            a) KVA
            b) Primary and secondary voltage
            c) Taps
            d) Primary and secondary continuous current
            e) Insulation class and temperature rise
            f) Sound level
         2. Circuit Breakers: Show circuit for which intended, voltage ratings, insulation level, current rating, and interrupting ratings.

D. Test Reports: Submit copies of certified reports of factory and field tests performed in accordance with the applicable referenced standards and specification requirements.
1.04 QUALITY ASSURANCE

A. Select a manufacturer who has been regularly engaged in the manufacture of similar equipment and has met UL requirements.

B. Conform to NEMA AB-1, NEMA PB1, UL 67 and National Electrical Code, as applicable.

C. Provide interchangeable components of the same type, size, rating, functional characteristics, and manufacture.

D. Verify each item is UL labeled.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Ship each unit securely wrapped, packaged, and labeled for safe handling in shipment and to avoid damage or distortion.

B. Store in secure and dry storage facility.

1.06 WARRANTY

A. Submit manufacturer's standard warranty.

PART 2 - PRODUCTS

2.01 EQUIPMENT

A. ENCLOSED CIRCUIT BREAKERS

1. Enclosed Circuit Breakers:

a. NEMA AB-1, molded case, quick-make quick-break bolt-on type, with thermal-magnetic type overload trip, interchangeable unit for frame rated 125 Amperes(A) and above.

b. Enclosure: NEMA 250 Type 3R, fabricated from galvanized steel, surface-mounted unless otherwise indicated.

c. Finish: metallic surface thoroughly cleaned, degreased, primed with an approved corrosion-inhibitive primer, and then finished with heavy-duty, industrial-grade polyurethane enamel.

B. PANELBOARDS AND MINI POWER CENTERS

1. Panelboards and Mini Power Centers: NEMA PB1 or UL 67

a. Enclosure: NEMA 250 Type 4X, fabricated from stainless steel, surface-mounted unless otherwise indicated, tamperproof, with the following additional requirements:
1) Gutter size:

<table>
<thead>
<tr>
<th>Rating (Amperes)</th>
<th>Main Bus</th>
<th>End Gutter</th>
<th>Side Gutter</th>
</tr>
</thead>
<tbody>
<tr>
<td>225 and below</td>
<td>6</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>400 and over</td>
<td>8</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

2) Provide backplate of reinforced steel for mounting of interior components.

3) Provide device or mechanism for enclosure grounding.

b. Cover and Trim:

1) Designed for surface or flush mounting as indicated.

2) Adjustment: Provide flush-mounted panelboards with means to plumb and align the front of the panel with respect to the adjacent finished surfaces.

3) Door: Hinged, fitted with a combination latch and door lock, accommodating a master key. Provide one flat key tumbler cylinder-type, nickel-plated door lock conforming to the station master key system, two keys per lock.

4) Circuit Directory: Provide a directory frame with acrylic plastic face mounted on the back of the door.

5) Finish: metallic surface thoroughly cleaned, degreased, primed with an approved corrosion-inhibitive primer, and then finished with heavy-duty, industrial-grade polyurethane enamel.

c. Bus Bars: ASTM B187, 98 percent conductivity copper, with silver-plated contact surface.

1) Provide neutral bus of the same rating as that of phase bus.

2) Provide a grounding bus.

d. Circuit Breakers

1) Bolt on type.

2) Auxiliary contacts: Ensure circuit breakers in tunnel lighting and power panels have auxiliary contacts and that these contacts are paralleled to provide a common panel trouble alarm locally and monitoring by SCADA (SCADA interface by others).

e. Mini Power Center

1) Each mini power center to include a primary main breaker, an encapsulated dry-type transformer and a load center with a secondary main breaker.
2) Primary main, secondary main and feeder breakers to be enclosed with a pad-lockable hinged door.

3) Insulate transformers with a 185 degrees C insulator system and rated at 115 degrees C

4) All insulation materials to be flame retardant and not to support combustion as defined in ASTM standard test method D635.

5) Provide transformer with two primary winding taps 2-1/2 inches above and below nominal

6) Provide two winding energy efficient taps with copper winding type transformers.

2.02 SOURCE QUALITY CONTROL

A. In addition to the manufacturer's standard tests, as a minimum perform the following tests at the manufacturer's plant:

1. 60 Hertz dielectric tests;
2. Mechanical operations tests;
3. Grounding of instruments;
4. Transformer case tests;
5. Electrical operation tests; and
6. Control wiring checks.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate installation of panelboards and mini power centers with requirements of Section 26 05 00, Common Work Results for Electrical, Section 26 05 25, Wire and Cable, Section 26 05 26, Grounding and Bonding for Electrical Systems, Section 26 05 33, Raceway and Boxes for Electrical Systems and 26 08 00, Commissioning of Electrical Systems.

B. Panelboard, Mini Power Center, and Enclosed Circuit Breaker

1. Mounting Height: Install with top 6 feet, 6 inches above the floor and the bottom not less than 12 inches above the floor, unless specifically indicated otherwise. Use multi-sectional panelboards and load centers to meet these spacings if necessary. Line up tops of trims to present neat appearance.
   a. Anchor in accordance with seismic requirements in Section 26 05 00, Common Work Results for Electrical.

2. When a feeder serves more than one panelboard or panelboard section, install a separate junction box or provide adequate gutter area for termination of feeders and bus taps.

3. Connect neutral wires of branch circuits to the neutral bar of the same
panelboard as the branch circuit.

4. When circuit breakers are located in spaces other than the main electrical distribution system equipment rooms and used to protect conductors serving emergency equipment motors (such as fans, dampers, and pumps), emergency lighting, and communications equipment, ensure they not be tripped by the thermal element. Use thermal element contact to indicate an alarm condition.

5. Provide nameplates or other permanent identification for each circuit breaker, mounted on the cover or trim adjacent to each breaker, in accordance with Section 26 05 53, Identification for Electrical Systems.

6. Provide each panelboard and mini power center with an accurate typewritten circuit directory. Install in the factory-provided directory frame mounted on the back of the door.

3.02 FIELD QUALITY CONTROL

A. Provide equipment for testing power and control circuits after installation. Test under the observation of the Resident Engineer.

1. Panelboards and Circuit Breakers:
   a. Test circuits for connections in accordance with the wiring diagram.
   b. Test that insulation resistance to ground of nongrounded conductors is a minimum of 10 megohms.
   c. Test panelboard and mini power center enclosures for continuity to the grounding system.
   d. Test operation of circuits and controls. When testing, operate each control a minimum of ten times and each circuit continuously for a minimum of 1/2 hour.
   e. Test that each panel has a balanced load.
   f. Maintain a log of tests.

3.03 DEMONSTRATION

A. Perform pre-energizing checkout procedure in accordance with NECA 400 prior to energizing switchboards.

B. Notify Resident Engineer prior to energizing switchboards.

C. Energize switchboards in accordance with NECA 402.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing enclosed switches and fuses.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common Work Results for Electrical

2. Section 26 05 26, Grounding and Bonding for Electrical Systems.


1.02 REFERENCES

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

1. American National Standards Institute (ANSI)
   a. UL 198C High Interrupting-Capacity Fuses; Current-Limiting Types
   b. UL 198E Class R Fuses

2. National Electrical Manufacturers Association (NEMA):
   a. NEMA KS 1 Enclosed and Miscellaneous Distribution Equipment Switches (600 Volts Maximum)
   b. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit manufacturers’ product data for specified equipment and materials. Include the following information for each item:

1. Outline drawings with dimensions

2. Equipment ratings for voltage, capacity, horsepower, and short circuit withstand.
PART 2 - PRODUCTS

2.01 COMPONENTS

A. Enclosed Switches

1. Fusible Switch Assemblies: NEMA KS 1; quick-make, quick-break, load interrupter enclosed knife switch with externally operable handle interlocked to prevent opening front cover with switch in ON position. Handle lockable in OFF position. Fuse Clips: Suitable for Class R or J fuses with fuse rejection devices installed.

2. Nonfusible Switch Assemblies: NEMA KS 1; quick-make, quick-break, load interrupter enclosed knife switch with externally operable handle interlocked to prevent opening front cover with switch in ON position. Handle lockable in OFF position.

3. Enclosures: NEMA KS 1; NEMA 250 Type 1, 3R, or 4X as required for the environment or as designated on the Contract Drawings.

B. Fuses

1. Fuses, 600 Amperes or Less: UL 198C, Class J or UL 198E Class RK1 or as indicated on Contract Drawings. 600 V rated, one-time, time delay, current-limiting type.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install disconnect switches where indicated on Contract Drawings with external handle centered 60 inches above finish floor or grade level.

B. Install fuse-rejection devices in fuse clips if required.

C. Install fuses in fusible disconnect switches.

D. Install enclosure grounding and test ground resistance to be within specified values listed in Section 26 05 26, Grounding and Bonding for Electrical Systems.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing individual motor starters, motor control centers, lighting contactors, and lighting control panels.

B. This section includes specifications for the factory installation in the Motor Control Center (MCC) of the sump pump controller specified in Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 23, Operation and Maintenance Data.
2. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping and Appurtenances.
3. Section 26 05 00, Common Work Results for Electrical.
4. Section 26 05 25, Wire and Cable
5. Section 26 05 26, Grounding and Bonding for Electrical Systems
6. Section 26 05 33 Raceway and Boxes for Electrical Systems
7. Section 26 05 53, Identification for Electrical Systems.
8. Section 26 08 00, Commissioning of Electrical Systems

1.02 REFERENCES

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

   a. ASTM A653/A653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM D2092 Guide for Preparation of Zinc-Coated (Galvanized) Steel Surfaces for Painting

2. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE 344 Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

3. National Electrical Contractors Association (NECA)
a. NECA 402 Recommended Practice for Installing and Maintaining Motor Control Centers

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA ICS2 Industrial Control Devices Controllers and Assemblies
   b. NEMA ICS6 Industrial Controls and Systems Enclosures
   c. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

5. Underwriters Laboratories (UL);
   a. UL 845 Motor Control Centers

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Shop Drawings: Submit shop drawings and electrical diagrams. Identify all electrical equipment technical data, ATS, breaker, starter, contactor, control transformers, and relay characteristics and settings data, including inrush current ratings of all coils, on shop drawings.

C. Manufacturer’s product data of manufactured materials and equipment.

D. Operational and Maintenance Data: Submit maintenance data and operating instructions in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:
   1. Summary of the equipment and its components;
   2. Manufacturer’s operating and maintenance instructions, parts list, illustrations, and diagram of components;
   3. Recommended list of spare parts; and
   4. Wiring diagrams.

E. Test Reports: Certified test reports of factory and field tests performed, verifying that performance of equipment meets specification requirements.

1.04 DELIVERY, STORAGE AND HANDLING

A. Ship each unit securely wrapped, packaged, and labeled for safe handling of shipment and to avoid damage or distortion.

B. Store motor control center (MCC) in secure and dry storage facility.

1.05 WARRANTY

A. Submit manufacturer’s standard warranty.
PART 2 - PRODUCTS

2.01 EQUIPMENT

A. Motor Starters

1. Ensure motor starters meet the requirements of NEMA ICS2, general purpose Class A, and the following additional requirements:


1) Type:
   a) For dry and dust-free indoor location: NEMA 250, Type 1 with drip shield.
   b) For damp and dusty indoor location: NEMA 250, Type 12.
   c) For outdoor location: NEMA 250, Type 3R.
   d) For areas subject to corrosion: NEMA 250 Type 4X


3) Finish: Painted finish for all ferrous and galvanized metal surfaces.

   a) Prepare ferrous metal surfaces for painting in accordance with standard industry practice.
   b) Prepare galvanized metal surfaces for painting in accordance with ASTM D2092.
   c) After pretreatment, prime-paint surfaces with an approved corrosion-inhibitive metal primer for ferrous or galvanized surfaces, as applicable.
   d) For the finish coat use heavy-duty, industrial-grade polyurethane enamel.

c. Provide auxiliary devices at each contactor meeting the following requirements:

1) Auxiliary devices shall be manufacturer’s standard products. Control diagrams shall show actual configuration including auxiliary devices.

2) Heavy-duty type relay: Select devices with a Contact rating of 20 amperes (A) at 120 volts (V) alternating current (AC) which operate satisfactorily at 120 degrees F.
d. Mount terminal blocks used at the contactor in the enclosure. Verify that each terminal block is able to accommodate two 14 American Wire Gauge (AWG) wires.

e. Wiring:

1) For the control wiring inside the contactor enclosure use minimum 16 AWG, stranded, thermoplastic-insulated wire, rated 105 degrees C, with red color for ac.

2) Use power cable of the same type and rating as control wiring, black color, and with capacity compatible with the contactor or breaker rating.

2. Manual Starters: Quick-make quick-break toggle mechanism, trip-free manual reset thermal overload relay, position indicator showing ON, OFF, and TRIPPEd positions, and red indicating light showing the CLOSED position.


a. 480 V primary to 120 V secondary control transformer with one fuse in the secondary circuit.

b. Two NO and two NC auxiliary contacts with provision for addition of two NO or NC contacts.

c. Indicating pilot lights on each unit enclosure. De-energized: GREEN; and energized: RED.

d. Control selector switch: HAND/OFF/AUTO

4. Combination Motor Starters: Rated 480 V, three phase or single phase, 60 Hertz. Meet the requirements for magnetic motor starters with the following additional requirements:

a. Provide one 480 V, three-pole, motor circuit protector type circuit breaker with current limiter with adjustable trip-point.

b. Provide externally mounted operating handle with position indicator showing ON, OFF, or TRIPPEd condition of the circuit breaker or disconnect switch as applicable. Install operating handle that is interlocked to prevent opening and closing of the door when the circuit breaker or disconnect switch is in the ON position. Provide defeater to bypass the interlock.

B. Motor Control Centers (MCCs)

1. Combination Motor Starter with Solid State Soft Starters for Sump Pumps in a Motor Control Center (MCC): MCC to be rated at 480 V, three phase with current ratings as shown in plans. Meet the requirements for motor starters and other control devices with the following additional requirements:

a. Provide automatic transfer switch (ATS) with rating as indicated. ATS to have full bypass features for both the normal power supply and standby power supply. ATS to be standard design suitable for the intended application inside the MCC for sump pump power supply.
b. Provide one main breaker and three individual feeder breakers, one for each pump soft starter. Feeder breakers to be 480 V, three-pole, motor circuit protector type with current limiter and with adjustable trip-points.

c. Provide completely assembled soft starter combining all necessary elements such as SCRs, bypass contactor, and overload in one very compact unit for each pump control based upon sensed water level. These starters to be fully wired and tested inside the motor control center.

d. Soft starter shall be current limiting type adjustable to allow starting inrush current to be controlled to minimize system voltage dip during pump starting mode. Include standard Kick start features that provide a current and torque "kick" for 0 to 2.0 seconds allowing greater initial current to develop torque needed during pump starting.

e. Include all motor protection and control features which includes, 1) built in overload, 2) selectable phase reversal protection 3) selectable current limit or ramp start 4) adjustable ramp times 5) adjustable torque control, 6) adjustable kick start control 7) Digital Interface Module, 8) control transformer with proper fuse protection, 9) 24V dc power supplies for the soft starters 10) Panel mounted indicating lights, 11) device name plates 12) selector switches for individual pump starter 12) common selector switch for all three pumps 13) internal wiring and terminal strips as needed and 14) PLC interface control as indicated in Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances.

f. Motor control center assembly to contain triplex pump control system which will include three individual soft starters, PLC, level sensors and level transducer (See Section 22 14 10, Tunnel Track Drainage Pumping Station Piping And Appurtenances and the Contract Documents) and three motor circuit protectors. Fully wire and test all equipment at the factory. Provide a terminal strip for remote alarm and indication of the pump running and high level alarm conditions. To the Building Management System (BMS) as indicated on Contract Drawings.

g. Provide externally mounted operating handle with position indicator showing ON, OFF, or TRIPPED condition of the circuit breaker. Pump running indication, pump selector switch as applicable. Install operating handle that is interlocked to prevent opening and closing of the door when the circuit breaker or disconnect switch is in the ON position. Provide defeater to bypass the interlock.

2. Motor Control Centers Wiring: NEMA; Class II, Type B.

3. Feeder Tap Units: Molded case thermal-magnetic circuit protectors as described above.

4. Voltage Rating: 480 volts, three phase, three wire, 60 hertz.

5. Horizontal Bussing: Tin plated insulated Copper with a continuous current rating as indicated Include tin plated copper ground bus for the entire length of the control center.

6. Vertical Bussing: NEMA ICS2; Tin plated insulated Copper
7. Integrated Equipment Short Circuit Rating: 35,000 amperes root-mean-square (RMS) symmetrical at 480 volts unless indicated otherwise on Contract Drawings.

8. Configuration: Units front mounting only, accessible from the front only.


10. Finish: Manufacturer’s standard gray enamel or as scheduled.

11. Seismic Requirements: IEEE 344; Class I.

C. Lighting Contactors

1. Contactors: NEMA ICS2; electrically-held, two-wire control.

2. Coil Operating Voltage: 277 volts, 60 Hertz.

3. Contacts: Silver alloy, fully rated for tungsten lighting loads, 20 A, 600 Vs or as noted on Contract Drawings.

4. Enclosure: NEMA 250, Type 4X. When mounted within equipment enclosures as a listed assembly, use open-type contactors.

5. Provide screw-terminals for termination of circuit conductors unless shown otherwise on Contract Drawings.

D. Lighting Control Panels

1. Provide industrial lighting control panel in NEMA 250 Type 4X cabinet for control of lighting systems. Ensure the control panel includes interface with Building Management System (BMS)-based network lighting controller as indicated on Contract Drawings, individual low-voltage relays rated for 20 A tungsten lighting or inductive loads, and ancillary equipment.

   a. Provide number of relays and switch inputs as noted on Contract Drawings but a minimum of 12 outputs and 8 inputs in each cabinet.

   b. Ensure control panel has the capability to manually override automatic relay control.

   c. Provide accessory equipment including under voltage relay device (27), 24V DC auxiliary relays, local start/stop pushbuttons, and terminal strips for interface with field wiring.

   d. Provide the following automatic and remote functions in the lighting control panel

      1) Provide local on/off push buttons installed at the controller front cover to bypass remote control of lighting.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Coordinate installation of enclosed controllers and MCC with requirements of Section 26 05 00, Common Work Results for Electrical, Section 26 05 25, Wire and Cable, Section 26 05 26, Grounding and Bonding for Electrical Systems, Section 26 05 33, Raceway and Boxes for Electrical Systems, and Section 26 08 00, Commissioning of Electrical Systems.

B. Section 22 14 10, Tunnel Track Drainage Pumping Station Piping, and install individual motor starters and contactors as indicated and as recommended by the manufacturer.

C. Install motor control centers as recommended by the manufacturer and in accordance with NECA 402.

D. Anchor equipment in accordance with the seismic requirements in Section 26 05 00, Common Work Results for Electrical

E. Select and install heater elements in motor starters to match installed motor characteristics.

F. Motor Data: Provide label on each motor starter enclosure door in accordance with Section 26 05 53, Identification for Electrical Systems

G. Install lighting contactors and lighting control panels in accordance with Contract Drawings and make field connections to remote switches and pilot devices.

3.02 FIELD QUALITY CONTROL

A. Provide equipment and instruments and perform the following tests:

1. Test circuits for connections in accordance with accepted wiring diagrams.

2. Test that insulation resistance to ground of non-grounded conductor is a minimum of 10 meg-ohms.

3. Test equipment enclosures for continuity to the grounding system.

4. Test operation of circuits and controls. When testing, operate each control a minimum of ten times and each circuit continuously for a minimum of 1/2 hour.

3.03 DEMONSTRATION

A. Perform pre-energizing checkout procedure in accordance with NECA 402 prior to energizing motor control centers.

B. Notify Resident Engineer prior to energizing motor control centers.

C. Energize motor control centers in accordance with NECA 402.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for corrosion control monitoring systems and electrical continuity for tunnel structures.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 33, Raceways and Boxes for Electrical Systems.

1.02 REFERENCES

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

1. NACE International (NACE)
   a. NACE RP0187-2002 Design Considerations for Corrosion Control of Reinforcing Steel in Concrete

2. National Electrical Manufacturers Association (NEMA)
   a. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

3. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electrical Code

4. Underwriters Laboratories (UL)
   a. UL 50 Enclosures for Electrical Equipment

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures

1. Assembly, erection, and installation drawings. Coordinate submittal with requirements of 26 05 33, Raceways and Boxes for Electrical Systems.

2. A complete list of tunnel corrosion control equipment and material, including name and manufacturer, catalog number, size, finish, and any other pertinent data necessary for proper identification and to determine conformance with the specifications.

3. Certification by the cable manufacturer covering conformance of cable insulation to the designated specification.

5. Qualifications of personnel performing and providing quality assurance for electrical tests required herein.

6. Quality control test procedure which includes the personnel to be utilized for the project, resumes and certifications, data sheets, procedures, test equipment calibration certificates, and other pertinent data for approval by the Resident Engineer.

7. Test Plan
   a. Preliminary Approval: Submit a detailed testing plan based upon the testing requirements included in these Specifications. Include:
      1) Measurement methodology in high resistance environments;
      2) Sample calculation formats;
      3) Expected range of values for each test procedure;
      4) QA/QC procedures;
      5) Sample data sheet and spreadsheet file showing the proposed format for test data documentation.
   b. Instruments: Submit list of instruments to be used. Include manufacturer, model number, serial number and calibration certificate for each instrument.

8. Parts and special tools list

B. Test Results and Calculations:
   1. Submit to the Resident Engineer within 10 Days of the performance of the test.
   2. Provide five copies of test results in typed format and signed by the NACE Specialist or Technologist performing the test procedure and the quality control review individual.

1.04 QUALITY ASSURANCE

1. An independent corrosion control organization shall supervise installation and perform installation testing of the corrosion control system including, but not limited to, electrical continuity testing. The organization shall have been continuously engaged in the field of corrosion control testing for a minimum of five years and shall have the following qualifications:
   a. NACE International Certified Cathodic Protection Specialists and Corrosion Technicians available to perform the required field testing.
   b. Work to be performed under the direct supervision of a NACE International Cathodic Protection Specialist.
   c. Testing organization employed for field quality control shall have a minimum of five years experience in the testing of corrosion control systems for tunnel structures of similar type and complexity as the system specified and indicated.
4. Testing shall be performed by personnel with at least five years of employment experience with testing corrosion control systems.

1.05 DELIVERY, STORAGE AND HANDLING

A. Materials and equipment to be used in construction shall be stored in such a manner to be protected from detrimental effects from the elements. If warehouse storage cannot be provided, materials and equipment shall be stacked well above ground level and protected from the elements with plastic sheeting or as appropriate.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Materials shall conform to the requirements set forth herein or as designated on the drawings, unless otherwise specified. Materials must be new, free from defects, and shall be of the best commercial quality for the purpose specified. Necessary items and accessories not shown on the Contract Drawings or specified herein, but which are required to fully carry out the specified intent of the work, shall be provided.

B. Steel Collector Cable

1. One inch diameter, unlubricated, bare, as shown on the Contract Drawings.

C. Wire and Terminations

1. Test Leads
   a. Type: Type XHHW-2 or RHH/RHW, unless otherwise indicated.
   b. Cables for steel cable test leads shall be #4 AWG, stranded, copper. Two test leads are required at each test box.
   c. Cables for electrically continuous reinforcing steel test leads shall be #4 AWG, stranded, copper. Two test leads are required at each test box.
   d. Terminations: Compression type ring tongue or spring spade terminals with insulated ferrules. Quick-connect terminations are not acceptable.

D. Test Boxes

1. Corrosion Control Test Box
   a. Provide test boxes sized and located as indicated on the Contract Drawings.
   b. Approved manufacturer and product: Hoffman, Inc., Model Q181813PCE, or approved equal.

2. Terminal Board
   a. Provide manufacturer standard, non-metallic, interior mounting panel.
   b. Provide nickel-plated brass termination hardware.
c. Approved manufacturer and product: Hoffman, Inc., Model Q1818PE, or approved equal.

E. Reference Electrodes
1. Silver/Silver Chloride Reference Electrode
   b. Provide with factory installed and sealed No.14 AWG red RHH-RHW insulated wire of sufficient length to reach to junction box termination point without splicing.
   c. Approved manufacturer and product: Borin, Model CRE-020-SCB or approved equal.

F. Exothermic Molds and Charges
1. Approved manufacturers: Cadweld by Erico Products, Inc., Thermoweld by Continental Industries, Inc., or approval equal.
2. Cartridge, sleeves and molds shall be furnished by the same manufacturer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General
1. Materials, workmanship, and installation shall as a minimum meet requirements of the National Electric Code and other applicable State, County, or City codes and regulations. Nothing in the Contract Documents is to be construed to permit work not conforming to these regulations and codes.

B. Wire and Cables
1. Cables shall be continuous in length and free of joints or splices. Care shall be exercised during installation to avoid punctures, cuts, and similar damage to insulation. Damage to insulation will require replacement of the entire cable length. Pull boxes and splice boxes shall be installed where shown and where otherwise required to facilitate installation of conductors and to comply with code requirements.
2. Provide compression terminals for wire terminations using tool recommended by manufacturer of terminations. Ensure connections withstand normal use without damage.

C. Exothermic Welds
1. Provide connections between copper conductors and steel cable and/or steel reinforcing using exothermic welding process, as recommended by manufacturer of exothermic weld equipment.
2. Provide copper sleeve on cables prior to welding. Materials for welding shall be sized in accordance with recommendations in manufacturer’s literature.
3. **Weld Testing:** After the weld has cooled and the slag material has been removed, test the weld by striking with a two-pound hammer at an angle of approximately 45 degrees to the surface while maintaining tension on the wire. Replace defective welds with new welds at no cost to Sound Transit. Maintain a minimum distance of 6 inches between exothermic welds unless otherwise approved.

4. **Exothermic Weld Protective Coating:** Coat welds and all steel within 2 inches of the weld with an approved coating material and provide mechanical protection. Coat exposed surfaces of copper. Provide surface preparation and apply coating as indicated by the coating manufacturer.

**D. Test Boxes and Cables**

1. Route test wires and reference electrode wires in conduit to designated test box.
2. Install test box wiring without tension on the wiring.
3. Terminate wire at both ends unless indicated otherwise.
4. After termination, test wires for electrical continuity by measuring resistance between same colored wires at test box. Acceptable resistance is no more than 1.10 times the theoretical resistance of the two wires after temperature compensation. Replace wires that do not pass test at no cost to Sound Transit.
5. Seal conduits and openings in test box, and install cover in accordance with manufacturer’s recommendations, to make a watertight enclosure.

**E. Reference Electrodes**

1. Install reference electrodes where indicated and route connecting wire to junction or test box as indicated on the Contract Drawings.

**F. Steel Collector Cable**

1. Install steel collector cable in one continuous length without splices between test boxes or between steel reinforced concrete and test boxes

**G. Reinforcing Steel**

1. Where steel reinforced concrete slab is utilized, the top layer of steel reinforcement shall be made electrically continuous through the use of lap splices along the longitudinal reinforcement and the installation of transverse bonding bars, as shown on the Contract Drawings. Transverse bonding bars shall be installed at each end of the slab, and at intermediate locations not to exceed 500 feet.

### 3.02 FIELD QUALITY CONTROL

**A.** Notify the Resident Engineer a minimum of two days before the performance of electrical testing.

**B.** After installation of the corrosion control facilities, the system shall be tested by a qualified Corrosion Engineer to ensure conformance with these Contract Specifications. Testing shall include adequacy of test stations and electrical continuity of the steel collector cable and steel reinforcing mat. Upon completion of the tests, a detailed written report shall be submitted describing any deficiencies detected. Deficiencies shall be
corrected by the Contractor at its cost and retested prior to final acceptance. Retesting shall be at no cost to Sound Transit.

C. Reference Electrode Testing

1. Test each reference electrode before placement of concrete. Place the calibrated electrode and the reference electrode in a non-metallic container containing ambient temperature tap water and use a high impedance voltmeter to measure the voltage between the two electrodes. If the voltage measured is more than plus/minus 15 millivolts from the manufacturer’s recommended differential voltage, reject the reference electrode.

2. Replace reference electrodes that fail the test at no cost to Sound Transit.

D. Steel Collector Cable Continuity Testing

1. Verify electrical continuity of the steel collector cable by measuring the longitudinal resistance. Acceptable resistance is no more than 1.10 times the theoretical resistance of the steel cable.

2. Testing shall be performed before and after concrete installation.

3. Any portion of the cable found which does not meet the above criteria shall be replaced at no cost to Sound Transit.

E. Reinforcing Steel Continuity Testing

1. Verify electrical continuity of the steel reinforcing collector mat by measuring the longitudinal resistance. Acceptable resistance is no more than 1.10 times the theoretical resistance of the steel reinforcing mat.

2. Testing shall be performed before and after concrete installation.

3. Any portion of the reinforcing mat found, which does not meet the above criteria shall be replaced at no cost to Sound Transit.

F. Final Approval: The Resident Engineer will observe the initial field tests. Should the procedures appear valid after two separate tests, final approval will be given. Do not vary or change the approved testing techniques without written approval from the Resident Engineer. Submittal of test results for non-approved test plans will be rejected.

G. Record results related to acceptance criterion, conditions at the work site, personnel performing the test, points of electrical connection, equipment and instrumentation used for the testing, specific measurement procedures, and general weather conditions.

H. Provide review of all test results and procedures performed by the NACE Specialist or Technologist for completeness and accuracy by an individual with qualifications and experience equal to or greater than the individual performing the testing.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 26 51 14
LIGHTING SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing luminaires, mounting hardware, and lamps for interior use inside the tunnel and tunnel cross-passages.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 26 05 00, Common Work Results for Electrical.
2. Section 26 05 25, Wire and Cable.
3. Section 26 05 26, Grounding and Bonding for Electrical Systems.
4. Section 26 05 33, Raceway and Boxes for Electrical Systems.
5. Section 26 05 53, Identification for Electrical Systems.
6. Section 26 08 00, Commissioning of Electrical Systems.
7. Section 26 24 16, Panelboards.
8. Section 26 29 13, Enclosed Controllers and MCC.

1.02 REFERENCES

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

1. American National Standards Institute (ANSI):
   a. ANSI C62.41 IEEE Recommended Practice on Surge Voltages in Low-Voltage Ac Power Circuits
   b. ANSI C78. Series Electric Discharge Lamps (Fluorescent), High Intensity Discharge Lamps (High Pressure Sodium), Method of Designation
   c. ANSI C81.62 Lampholders for Electric Lamps
   d. ANSI C82.4 Standard for HID Ballasts

   b. ASTM A167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
3. Illuminating Engineering Society of North America (IES):
   a. IES Lighting Handbook, Reference and Application

4. National Electrical Contractors Association (NECA)
   a. NECA/IESNA 502 Recommended Practice for Installing Industrial Lighting Systems

5. National Fire Protection Association (NFPA):
   b. NFPA 130 Fixed Guideway Transit And Passenger Rail Systems

6. Porcelain Enamel Institute (PEI):
   a. PEI-1001 Specifications for Architectural Porcelain Enamel

7. U.S. Environmental Protection Agency (EPA)
   a. 22 CCR Section 6260.200 (e) Toxic Characteristic Leaching Procedure (TCLP).

8. Underwriters Laborites inc. (UL)
   a. UL 542 Lamp holders, Starters, and Starter Holders for Fluorescent Lamps
   b. UL 1029 High-Intensity-Discharge Lamp Ballasts
   c. UL 1570 Fluorescent Lighting Fixtures
   d. UL 1572 High intensity Discharge lighting Fixtures.
   e. UL 1598 The Standard for Safety of Luminaires
   f. UL 844 Luminaires for Use in Hazardous (Classified) Locations

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data Luminaire Manual: Submit luminaire data manual documenting that luminaires, ballast and lamps fully comply with Contract Documents and indicating luminaire construction, photometric performance, installation, and maintenance requirements. Prepare the manual by the authorized manufacturer’s representative serving the project area and include the following information and exhibits:

1. Complete the manual with cover, title page, and table of contents. The cover and title page identify the document, project, client, Contract name, number and date of issuance. The table of contents to provide at a glance, the overall document scope and structure and, as a minimum, a heading for each luminaire type with each grouping prefaced by a general information report sheet.
2. Clear and legible product specifications, drawings, and illustrations of sufficient detail to describe the following:
   a. Luminaire housing, hardware, and finishes;
   b. Light controlling elements;
   c. Electrical components, including lampholders, ballast, and provision for conduit entry; and
   d. Support details including foundation. Indicate weight of luminaire, complete with lamps.

3. Procedures for installation of the complete lighting unit in its final service location. Provide dimensions to locations of openings and parts interfacing with remote systems, such as mounting hardware, auxiliary electrical equipment, lighting control equipment, and lamps.

4. Photometric reports from an certified Independent Testing Laboratory for each luminaire type.

5. Operation and maintenance requirements in accordance with Section 01 78 23, Operation and Maintenance Data, and the following information:
   a. Materials and components clearly indicated in the parts list;
   b. Relamping methods;
   c. Special tools required; and
   d. Frequency of inspection, tightening, or other service recommended for preventative maintenance.

6. Include within the submittal a list of manufacturer's representatives (including mailing address, e-mail address, and telephone and fax numbers) identifying which luminaire types they represent.

C. Samples: Submit one complete luminaire of each type indicated on Contract Drawings. Each sample requires the Resident Engineer's approval and, once submitted, become the property of Sound Transit. Approved samples will become the Resident Engineer's control samples. Provide samples complete with all housing and trim components in color specified, support accessories, 277 volts(V) ballast.

1.04 DELIVERY, STORAGE, AND HANDLING

A. Handle and transport products in a manner that prevents damage.

B. Indelibly mark each carton with minimum 1/2-inch high letters containing the following information:
   1. Luminaire, lamp, or component type.
   2. Quantity.
   3. Manufacturer's name and product number.

C. Store products in a clean, dry, and secure storage area pending installation.
1.05 WARRANTY

A. Ballasts: Provide manufacturer’s standard warranty.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Luminaires

1. Luminaire schedule catalog numbers shown on design drawings package are a reference to manufacturer design series and do not necessarily reflect the exact catalog number, size, voltage, wattage, type of lamp, ballast, finish trim, ceiling type, mounting hardware, ceiling trim or special requirements. Indicate luminaire voltages on Contract Drawings.

2. Provide luminaires, complete and ready for service in accordance with UL157 and UL1572. Provide luminaires of the number, type, material, finish, electrical components, characteristics, and with the necessary hardware and auxiliary equipment, as indicated. List luminaires with provisions for raceways for this as being for this use. Comply also with applicable requirements and guidelines of the IES Lighting Handbook.

3. Mark luminaires clearly with manufacturer's name and catalog number, voltage, acceptable lamp type, maximum wattage input, and label for intended use.

4. UL labeled and listed for the location and application intended.

5. Free of light leaks and designed to provide required ventilation for electrical components. Verify control temperature of lamps such that lamps reach full light output under installed environmental conditions.

6. For adjustable luminaires, provide positive locking devices to fix aiming angle. Verify luminaires are capable of being relamped without affecting aiming angle.

7. Provide safety devices for removable luminaire elements (cones, reflectors and lenses) to support removable elements when not in normal operating position. Provide safety devices that are detachable if necessary and do not interfere with luminaire performance, maintenance, or the seating of any luminaire element, and not be visible during normal operation.

B. Materials

1. Supply products of thicknesses, gages, and tempers as indicated, and as recommended by the manufacturer for the specific finish, proper forming operations, and structural requirements.

2. For reflector material use prefinished, copper-free aluminum alloy, minimum thickness 0.032 inch, Architectural Type 1 with Class M1 anodic coating providing 83 percent reflectivity.

3. Acrylic for lenses and diffusers: manufactured from virgin-acrylic extrusion or injection molding pellets.

4. Polycarbonate for lenses: manufactured from high temperature resin designed for use with HID lamps.
5. Glass for lenses: tempered borosilicate pressed or spun glass, minimum 0.13 inch thick.


C. Finishes

1. Provide luminaires completely factory-finished in colors to match the Resident Engineer’s control samples and in accordance with the manufacturer’s recommendations for the specific application.

2. Do not start finishing operations until fabrication and forming operations have been completed.

3. Finish ferrous mounting hardware and accessories to prevent corrosion and discoloration of adjacent materials. Where aluminum parts come into contact with bronze or steel parts, apply a permanent finish to both surfaces to prevent corrosion.

4. Anodized aluminum: Class 1 anodic coating.
   a. In accordance with procedures established by alloy manufacturer to achieve color within specified range.
   b. Apply a clear organic protective coating to exposed aluminum surfaces that experience prolonged contact with caustic material such as concrete or plaster.

5. Clean metal before painting using a five-stage phosphatizing system consisting of alkali cleaner, hot water rinse, zinc phosphatizing solution with toner, water rinse at room temperature, and chromic acid rinse for neutralizing.

6. Statically charge and paint interior luminaires with surfaces not exceeding 150 degrees F. Paint with a minimum of two coats of acrylic gloss enamel to a minimum total dry film thickness (DFT) of 2.5 mils.

7. Interior luminaires with surfaces exceeding a temperature of 150 degrees F, but not exceeding 300 degrees F, shall be charged and painted with silicone-alkyd enamel, two coats minimum to a total DFT of 2.5 mils.

8. For exterior or corrosive locations, finish luminaires and accessories with weather-resistant enamel using proper primers or bondered epoxy over galvanized surfaces. The entire luminaire assembly shall be corrosion-resistant under the installed service conditions.

9. For finish luminaires specified to be porcelain enameled, or painted luminaires with reflectors specified to be porcelain enameled, coat them in accordance with the requirements of PEI-1001.

10. Finish reflective surfaces that are not specified to be specular to be gloss white, guaranteed non-yellowing, with a reflectance rating of not less than 88 percent.

11. Provide galvanized coating where indicated. Hot-dip galvanizing according to ASTM A123/A123M. Where painting of the galvanized surface is indicated, pretreat the surface with a spray of zinc chromate-vinyl butyryl wash primer at least 0.05 millimeters thick; apply an 80 percent zinc dust, 20 percent zinc oxide, alkyd resin primer; and then apply a single-component, Type II, modified acrylic or polyurethane top coat.
D. Light Control Elements

1. Reflector Cones:
   a. Provide minimum 45-degree lamp and lamp image cut-off for vertically mounted lamps. Provide minimum 30-degree lamp and lamp image cut-off for horizontally-mounted lamps.
   
   b. Do not use plastic materials for reflector cones, unless noted otherwise in the Luminaire Schedule.
   
   c. Do not rivet or weld reflector cones to housing and ensure reflector cones are removable without tools. Provide retention devices that do not deform the cone. Install trim flush with finished ceiling without gaps or light leaks. Where the flange trim is separate from the cone, install with the same finish as the cone unless otherwise noted.
   
   d. Uniform gage, not less than 0.032-inch, high purity aluminum alloy, free of spin marks or other defects.
   
   e. Reflectors: Alzak or approved equal finish.

2. Fresnel Lens and Door Assembly:
   a. Provide lenses that have uniform brightness throughout the entire visible area at angles from 45 degrees to 90 degrees from vertical, without bright spots or striations.
   
   b. Provide lenses that have opaque risers painted neutral gray unless otherwise specified in the luminaire schedule.
   
   c. Finish regressed door with matte, baked enamel paint in color as selected by Resident Engineer.

E. Electrical Components:

1. Lampholders:
   a. Provide lampholders and sockets in accordance with ANSI C78.380 and C81.62 and of the class and style recommended by the lamp manufacturer for the specific lamp required for each luminaire design and rated for 660 watts (W), 600 V, or as indicated.
   
   b. Design to hold lamps securely and withstand normal vibration and maintenance handling.
   
   c. Fasten lampholders and sockets rigidly and securely to the mounting surface with the necessary provisions to be front removable without dismantling any part of the luminaire, and to prevent lampholder from turning.
   
   d. Locate lampholders and sockets correctly in the luminaires to place each specified lamp in proper position with relation to the luminaire design and to ensure proper distribution of light. Clearly mark lampholders and sockets to indicate manufacturer, lamp type, voltage, and appropriate listings.
e. Provide incandescent and high intensity discharge lampholders of glazed porcelain body with nonferrous metal components of heavy duty vibration resistant design.

1) Provide phenolic body, double contact, bayonet sockets rated 75 W, 125 V, for special compact fluorescent and low wattage incandescent lamps such as the 20 W T6-1/2.

2) Provide a high voltage mogul lampholder, 5 kilovolts (kV) pulse rated, 1.5 kilowatts (kW), 600 V, for metal halide and high-pressure sodium lamps 250 W and up to and including 1 kW.

f. Provide fluorescent lampholders of white urea, spring loaded with silver-plated contacts of the pedestal or button type in accordance with UL 542.

g. Lampholders of the tombstone or butt configuration.

h. Supply miniature fluorescent preheat and circline lamps which use special lampholders as recommended by the individual lamp manufacturer.

2. Ballasts:

a. High efficiency, with high power factor (higher than 0.9) by the use of capacitor, with current crest factor of 1.6 or less and a minimum starting temperature of minus 20 degrees F. Ensure the ballast allow plus or minus 5 percent lamp watts variation for a plus or minus 10 percent input voltage variation.

b. Mount each ballast securely inside the luminaire to obtain the necessary heat dissipation. Ensure high intensity discharge ballasts comply with UL 1029 and ANSI C82.4.

c. For fluorescent lamps matches the characteristics of the lamps, and meet the following requirements:

1) Operate lamps at a frequency of 20 kilohertz or higher without visible flicker.

2) Be listed Class P for indoor or Type 1 outdoor applications.

3) Have total harmonic distortion of less than 10 percent at 277 V.

4) Have current crest factor of less than 1.5.

5) Have a power factor of 0.98 minimum.

6) Have an audible noise rating of Class A or better.

7) Contain no Polychlorinated Biphenyls (PCBs).

8) Comply with ANSI C62.41, Category A, for transient protection.

9) Have inherent thermal protection.

10) Provide constant light output with input voltage fluctuation of plus or minus 5 percent.
11) Provide instant-start for parallel wiring connection of lamps. Allow remaining lamps to maintain full output, in the event of lamp failure on multiple lamp luminaire.

12) Provide reliable lamp starting at 0 degrees F for luminaires located in unheated interior spaces and at 50 degrees F for luminaires located in heated interior spaces.

3. Luminaire Wiring:
   a. Stranded tinned-copper construction, not smaller in wire size than 16 AWG. Provide insulation of silicone rubber type SF-2, 200 degrees C rated. Mark conductor size, temperature rating, voltage, and manufacturer clearly on the insulation of each conductor.
   b. Provide wires between lampholders and associated operating and starting equipment with the same ampacity rating as leads from the ballast.
   c. Comply with the National Electrical Code.
   d. Tape wires at points of abrasion. Do not permit splices within luminaires other than as required to connect lampholders and ballast. Provide wireways and wiring channels with rounded edges or bushed holes wherever conductors pass through. Install insulated bushings at points of entrance and exit of wiring.
   e. Flexible cord wiring between luminaire components and to electrical receptacle, but not in wireways, shall have a minimum temperature rating of 105 degrees C.
   f. Fit Cords with proper strain reliefs and watertight entries where used for damp or wet location luminaires.
   g. Master/Slave luminaires: Supply ballasts in adjacent luminaires to operate one or more lamps in the adjacent luminaire where required by Contract Drawings. For single lamp luminaires, provide a two-lamp ballast for two adjacent luminaires. For three lamp luminaires, provide one two-lamp ballast for the outboard lamps and additional two-lamp ballast for the center lamp in both luminaires.
   h. Tandem-wired luminaires: For luminaires in continuous rows and where required by Contract Drawings, supply ballasts and wiring to control all top or inboard lamps together and control all bottom or outboard lamps together.
   i. Dual-level switched luminaires: Provide multi-wire, flexible luminaire whips as required for luminaires designated as dual-level switched on the Contract Drawings.

4. Luminaire Grounding: Unless otherwise specified, provide the housing of each ballasted luminaire with a separate, factory-installed grounding device. Attach a separate grounding conductor to the grounding device on each luminaire housing.

F. Luminaire Hardware:
1. Ensure latch and release mechanism, hinges, pins, and other retaining parts of luminaires; screws, bolts, or other assembly and mounting parts are manufactured of Type 304 or Type 316 stainless steel. Provide springs of heavy duty stainless steel. Provide self-retaining type retaining hardware.

2. Ensure light transmitting panels are held in the frames in a neat, rattle-free manner that will provide proper tolerance for normal expansion and contraction.

3. Fabricate internal brackets from ASTM A366/A366M sheet steel, zinc-coated after fabrication, or finished extruded aluminum.

4. Ensure that gaskets, sealants, and adhesives are formed from silicone rubber, or as indicated.

5. Provide bolts, nuts, washers, screws, nails, rivets, and other fastenings necessary for proper installation or assembly of work. Verify that items exposed to the atmosphere are made of 300 series stainless steel. Ensure fastenings within the housing are hot-dip galvanized steel and that nuts have captive externally-footed lockwashers.

6. Junction boxes suitable for the intended location and wiring requirements are provided with four 3/4-inch threaded and plugged conduit entries.

2.02 LUMINAIRE MOUNTING HARDWARE

A. Provide luminaires with brackets, straps, canopies and stems, and miscellaneous hardware suitable for the mounting method specified.

2.03 LAMPS

A. Provide each luminaire with the number, type, and wattage of lamps as indicated. Lamps used in the illumination system of standard manufacture, readily available, and of the highest efficiency and life consistent with other requirements of the illumination system. Ensure each type of lamp of is provided by a single manufacturer.

B. Fluorescent Lamps:

1. Energy-efficient T8, rapid start fluorescent lamp rated 265 milliamps (mA), wattage rating as indicated. Use lamps for T8 fluorescent lighting that have reduced mercury contents that meet U.S. Environmental Protection Agency (EPA) Toxic Characteristic Leaching Procedure (TCLP) test for nonhazardous fluorescent light waste pursuant to 22 CCR Section 66260.200 (e).

2. Rated minimum average life of 30,000 hours, minimum 78 Color Rendering Index (CRI), and minimum 3500 degrees K Correlated Color Temperature (CCT).

C. High Pressure Sodium Lamps: Clear or coated as indicated, suitable for all operating positions. Ensure Lamps have a rated minimum average life to 15,000 hours, minimum 60 Color Rendering Index (CRI) and minimum 2200 degrees K Correlated Color Temperature (CCT).

D. Light-Emitting Diode (LED) Part of Blue light stations: Super bright solid state LED lamps conforming to NFPA 101B requirements for luminous retrofit, surge protected, minimum rated LED life of 25 years, and complying with ANSI C62.41.
2.04 STANDARD LUMINAIRES

A. Tunnel Luminaires

1. General: 4'-0" surface fluorescent with curved lens and stainless steel end caps to secure the lens. 2-lamp, 32W, T8, high-output ballast. Paramount Craft Lite or equal.

2. Listings: UL 1598 Wet Location, UL 844 Class I, Division 2

3. Housing: 20 GA (.036) zing coated steel or 304 stainless steel. Double channel, one welded inside the other with end caps. Threaded hubs welded to channel ends for watertight wireway access.

4. Reflector: Zinc coated steel or stainless steel painted with minimum reflectance of 88%

5. End Caps: 18GA stainless steel. Threaded ring secures end cap to housing.

6. Gasketing – EPDM

7. Lens: 0.140 Prismatic acrylic

8. Finish: Two mil white polyester enamel. Unpainted if stainless steel

B. Cross-passage luminaires

1. Same as tunnel luminaire except ceiling mounted.

2.05 LIGHTING CONTROL PANELS

A. Include contactors, terminal strips and control wiring as indicated in the Contract Drawings and in accordance with Section 26 29 13 Enclosed Controllers and MCC.

2.06 SOURCE QUALITY CONTROL

A. Test a typical representative unit of each luminaire that is clean, free from mechanical defects, equipped with the proper fittings, and with the lamp of the size and type in the position recommended for service operation.

B. Test UL-listed material, equipment, and components in accordance with UL standards. Test material, equipment, and components not covered by UL standards in accordance with nationally recognized standards. Provide material, equipment, and components bearing a label tag or certification of such inspection.

C. Perform and report tests for photometric performance in accordance with the approved methods outlined by the IES Lighting Handbook for photometric testing, and include data on candlepower, distribution, zonal lumens, maximum luminance values, and luminaire efficiency, including complete coefficients of utilization tables to indicate compliance with performance requirements.

PART 3 - EXECUTION

3.01 INSTALLATION

1. Coordinate installation of lighting systems with the requirements of Section 26 05 00, Common Work Results for Electrical; Section 26 05 25, Wire and
Cable; Section 26 05 26, Grounding and Bonding for Electrical Systems; Section 26 05 33, Raceway and Boxes for Electrical Systems; Section 26 05 53, Identification for Electrical Systems; Section 26 08 00, Commissioning of Electrical Systems; Section 26 24 16, Panelboards; and Section 26 29 13, Enclosed Controllers and MCC.

B. Luminaires

1. Inspect surfaces and structures to, and on, which products will be installed before the work of this Section begins, and ensure that these surfaces are capable of supporting the products. Finish surfaces that will be concealed by products before products are installed.

2. Install luminaires as indicated and in accordance with the manufacturer's installation instructions and recommendations, and in accordance with NECA/IESNA 502, complete with lamps, hangers, brackets, poles, fittings, and accessories, ready for operation.

3. Install exposed parts of luminaires after construction, painting, and general cleanup in the area has been completed.

4. Align, mount, and level luminaires uniformly. Avoid interference with, and provide clearance for, the equipment. Where the indicated locations for the luminaires conflict with the locations for other equipment, change the locations for the luminaires by the minimum distances necessary and as approved by the Resident Engineer.

5. Anchor luminaire supports to the structural slab or to structural members as indicated. Use supports to maintain the luminaire positions after cleaning and relamping. Provide supports for seismic loading in accordance with seismic requirements in Section 26 05 00, Common Work Results for Electrical.

6. Bracket surface-mounted luminaires rigidly from the mounting surfaces. Provide 1/4-inch clearance between surfaces when the luminaire is flat-mounted against concrete surfaces. Install luminaires with a noncumulative dimensional alignment tolerance of 1/16 inch when mounted in continuous runs with 1-inch spacing between individual luminaires. Ensure nipples carrying wires between luminaires are watertight.

7. Where aluminum is placed in contact with dissimilar materials, except galvanized steel, zinc, or stainless steel, treat contact surfaces as follows:
   a. When in contact with dissimilar metals, apply a prime coat of zinc chromate primer followed by two coats of aluminum and masonry paint.
   b. When in contact with concrete, masonry, and plaster, apply to aluminum contact surfaces zinc chromate primer, bituminous paint, aluminum and masonry paint, or pressure-sensitive tape.
   c. When in contact with wood or other absorptive materials, apply two coats of aluminum house paint to such materials, and protect aluminum contact surfaces with bitumastic paint.

8. Provide required lamps in each luminaire as soon as luminaires are properly installed.
9. Refer to architectural reflected ceiling drawings to coordinate luminaire locations with mechanical and fire protection equipment. Notify Resident Engineer of all conflicts.

10. Install luminaires with ventilation openings clear of obstruction.

11. Adjust variable-position lampholders to proper lamp position prior to luminaire installation.

12. For pendant-mounted luminaires, mounting height is from finished ceiling to top of luminaire.

13. Provide 72-inch flexible conduit whip for recessed luminaires located in suspended ceilings.

C. Ballasts

1. Install ballasts, other than those mounted integrally within luminaires, in such a manner that the ballast is protected from weather, moisture, and other atmospheric conditions, and in ambient temperatures that will not cause the temperature of the ballast housing hot-spot to exceed manufacturer’s requirements.

2. Ensure voltage drop to lamp, due to remote ballast mounting, does not exceed 1 percent of the nominal lamp voltage. Provide secondary ballast conductors with 1 kV insulation. When more than one ballast is mounted at one location, install with the minimum spacing between ballasts being 6 inches in a horizontal direction and 12 inches in a vertical direction. Mount ballast components securely inside the luminaire in such a manner as to obtain the necessary heat dissipation.

3.02 FIELD QUALITY CONTROL

A. Deliver luminaires and lighting equipment to the Project Site complete with related items, completely wired and assembled.

B. Inspect luminaires, lamps, and associated hardware before and after installation to ensure that they are of the quality and type specified and indicated, and are free of defects and damage.

C. Whenever practicable, test lighting systems at the same time that the distribution panelboard or switchboard is tested.

D. Adjust aperture rings on recessed luminaires to be flush with the finished ceiling.

E. Replace luminaires and components with damaged finishes or repair them to the satisfaction of the Resident Engineer prior to project closeout.

F. Install new lamps in luminaires with failed lamps not earlier than 48 hours before the date of final inspection.

G. Replace lamps that fail within 90 days after final Acceptance without additional cost to Sound Transit.

H. After installation of the lighting systems, turn off the normal lighting system and measure the emergency lighting levels along the walkways and the crosspassages. Lighting levels shall not be less than 0.25 ft-candles at the walking surface.
3.03 SPARES

A. Number of spares and spaces: Provide on each lighting panelboard as indicated on the Drawings and specified, as a minimum.

B. Fixtures and Mounting Accessories: 1 spare for each type.

C. Lamps: 10 percent of quantity furnished, minimum of two of each size and type.

D. Lenses: 3 percent of quantity furnished, minimum of one of each size and type.

E. Ballasts: 3 percent of quantity furnished, minimum of one of each size and type.

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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, maintaining, monitoring and decommissioning instrumentation which monitor earth and structure movements, groundwater drawdowns, and structural loads during Work.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
2. Section 01 57 15, Temporary Construction Noise and Vibration Control
3. Section 01 71 30, Protection and Maintenance of Property and Work.
4. Section 03 05 15, Portland Cement Concrete.
5. Section 31 09 13.50, Tunnel Instrumentation and Monitoring.
6. Section 31 23 19, Dewatering.

1.02 REFERENCES

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

1. Washington Administrative Codes (WAC)
   a. WAC 173-160 Minimum Standards for Construction and Maintenance of Wells
   b. WAC 173-162 Rules and Regulations Governing the Regulation and Licensing of Well Contractors and Operators

2. Revised Code of Washington (RCW)
   a. RCW 18.104 Water Well Construction Act

3. [City of Seattle (COS): Standard Specifications for Road, Bridge and Municipal Construction.]

4. American Association of State Highway and Transportation Officials (AASHTO):

5. American Petroleum Institute (API):
   a. RP 13A Drilling Fluid Materials.
American Society for Testing of Materials (ASTM)


b. ASTM D480 Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), Sch 40 and Sch 80


1.03 DEFINITIONS

A. Instrument Well: A well in which pneumatic, electric, or hydrological instrumentation is permanently or periodically installed to measure or monitor subsurface strength and movement. Instrument Well includes bore hole extensometers, slope indicators, pneumatic or electric pore pressure transducers, and load cells.

B. Maximum Level: Maximum allowable value for a specific geotechnical instrument.

C. Replacement Level: Value at which utilities are required to be replaced between points of zero settlement.

D. Trigger Level: Intermediate value less than the Maximum Level for a specific geotechnical instrument that serves as a trigger for additional remedial measures to be implemented.

E. Well: Water wells, resources protection wells, Instrument Wells, dewatering wells, and geotechnical soil borings.

F. Instrument: Survey systems, including surface, structure, soldier pile, wall and utility settlement points, strain gages, instrument wells and geophones,

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Instrumentation Installation, Monitoring and Transition Plan: Within 45 days of Notice to Proceed.

C. Corrective Action Plan: Within 45 days of Notice to Proceed.

D. Well Decommissioning Work Plan: Within 45 days of Notice to Proceed.

E. Manufacturers’ Product Data for all types of instruments to be installed, including calibration certificates.

F. Qualifications of Instrumentation Specialist, surveyor, and well driller for well decommissioning.

G. Copies of Start Cards and approved variances for all Instrument Wells.

H. Logs of borings of Instrument Wells, including sample data (depth, SPT N-Values) and Soil Descriptions of each sample.
I. Within five working days after approval of each instrument type, two sets of operating manuals for each type of instrument, including read-out devices and appurtenant equipment required for a complete installation.

J. Within five working days after completion of installation of each instrument, submit location data as required by the instrumentation schedule shown on the Contract Drawings.

K. Monitoring Data.

L. Provide post-decommissioning submittals to the Resident Engineer within 10 calendar days after completion of the work. These include, but are not limited to, well abandonment logs, waste characterization analytical test results, waste disposal certificates, and other completed forms and documents required by the Washington State Department of Ecology and other permitting agencies.

M. Monitoring Plan for Contractor Designed Temporary Shoring.

1. Instrument types, locations, action levels, and monitoring frequencies in accordance with the requirements specified here in.

1.05 QUALITY ASSURANCE

A. Perform all instrumentation activities described in this Section, including procurement, under the direct supervision of an Instrumentation Specialist retained by the Contractor and approved by Sound Transit. The Instrumentation Specialist may be an independent individual or employee of an engineering firm, testing laboratory, or similar organization. The Instrumentation Specialist shall be licensed as a Professional Engineer or Geologist registered in the State of Washington with a minimum of five years experience designing, installing, and monitoring instrumentation systems similar to those described in this Section. Demonstrate experience by resume and references.

B. Perform all surveying activities under the direct supervision of a licensed Professional Land Surveyor registered in the State of Washington.

C. Calibration

1. Calibrate all instruments prior to installation.

2. Verify calibration results are within the tolerances for the particular instrument as listed on the manufacturer’s standard published data sheet for that instrument. Instruments with calibration results that do not fall within the specified tolerances will be rejected.

3. Recalibrate inclinometers, survey instruments, readout units, and other equipment that is used for monitoring on an on-going basis at the manufacturer’s recommended intervals, or whenever, in the opinion of Sound Transit or the Contractor, there is reason to suspect that the associated data is being affected by calibration changes or errors.

4. Perform all calibration in accordance with the instrument manufacturer’s recommended methods.

5. Ensure calibration equipment and standards are traceable to National Institute of Standards and Technology standards and are themselves in current calibration. Submit evidence of traceability and calibration of standards to the Resident Engineer upon request.
D. Sound Transit may observe instrumentation activities. Sound Transit may also conduct Quality Assurance monitoring of instrumentation. Make the site available and otherwise accommodate these activities.

E. Sound Transit will test instruments for proper function upon completion of installation. Provide assistance to Sound Transit in testing instrumentation. Information will be made available to the Contractor within five days after testing.

F. Complete well decommissioning using a well driller licensed in the State of Washington.

1.06 DELIVERY, STORAGE AND HANDLING

A. Store all instrumentation and related materials in a secured area on site. Provide access to be freely available to Sound Transit.

B. Store all instruments within temperature and humidity limits recommended by manufacturers.

C. Protect the instruments from damage during storage, handling, and other operations.

D. Avoid introducing dirt, dust, or other foreign material into instrument sensors, leads, or other components.

E. Comply with all other recommendations of manufacturers for storage and handling.

1.07 PROJECT CONDITIONS

A. Availability of Data

1. Monitoring data becomes the property of Sound Transit and are not to be disclosed to third parties or published without written permission of Sound Transit.

2. Submit all monitoring data to the Resident Engineer within 24 hours of being acquired.

3. Data developed by Sound Transit will be available to the Contractor within 24 hours of being acquired.

B. Permits and Coordination

1. Sound Transit will acquire all permits, access agreements and other authorizations necessary to perform the instrumentation work described in this Section on private property, per Section 01 41 26, Permits. Sound Transit will provide copies of all documents to the Contractor at the Preconstruction Meeting.

2. Sound Transit will acquire a Project Construction Permit (PCP) to perform the instrumentation work described in this Section and shown on the Contract Drawings within the public right of way.

3. Coordinate activities affecting utilities with the appropriate utility company.

4. Pre-construction utility surveys: In accordance with Section 01 71 30, Protection and Maintenance of Property and Work.

5. Pre-construction building surveys: In accordance with Section 01 71 30, Protection and Maintenance of Property and Work.
C. Coordination of Instrumentation with Other Contracts

1. Instrumentation has been installed at the Brooklyn and Roosevelt Stations as part of previous contracts. Maintain and monitor this instrumentation as specified herein.

2. At Substantial Completion, coordinate with the follow-on contractor to take over responsibilities for maintaining and monitoring instrumentation around the Brooklyn and Roosevelt Stations.

3. Reference Section 01 12 19, Contract Interface, and the Contract Drawings for additional information and requirements.

D. Work Within Environmental Sensitive Areas

1. Areas are indicated on the Contract Drawings.

2. At a minimum, perform the following:
   a. Place orange fence around the perimeter of work areas.
   b. Avoid critical root zones of existing vegetation.
   c. Locate installations where there is an existing path or paved area.
   d. Restore any disturbance to sites to original conditions.

3. Notify the Resident Engineer prior to the start of work within these areas.

1.08 INSTRUMENTATION INSTALLATION, MONITORING AND TRANSITION PLAN

1. Schedule and outline of procedures and timing for installation of instrumentation:
   a. Summary table for all instrument installations by number and location showing timing of installation
   b. Initial monitoring readings schedule.

2. Manufacturer's descriptive literature, including technical specifications, for proposed instruments.

3. Manufacturer's literature on protective enclosures.

4. Detailed manufacturer's literature on installation procedures for each instrument, including cable and tubing locations, and methods for protecting instruments during construction.

5. Materials for grout backfill.

6. Calibration certificates for each instrument. Verify calibration sheets include at a minimum the zero correction value, the gauge factor, temperature correction factor, and calibration data at the time of manufacture.

7. Sample reports for each instrument type.
   a. Description of the instruments to be used.
   b. Description of installation procedures.
c. Plan showing proposed instrumentation locations, locations of data loggers or computers, cable routing to data loggers or computers, communication systems (if used)

8. Instrument Monitoring
   a. Baseline Readings
   b. Routine Monitoring
   c. Action Level Monitoring
   d. Coordination with in-tunnel monitoring data at cross-passages, in accordance with Section 31 19 13.50, Tunnel Instrumentation and Monitoring.
   e. System Maintenance
   f. Instrument replacement procedures: If an instrument is repaired, replaced or moved subsequent to installation record, submit new instrumentation type, as built location, and calibration sheets. Report the reason the original instrument was altered and the date the new instrument was operational.

9. Reporting of Monitoring Data
   a. Description of Instrumentation Data Management System (IDMS)
   b. How data is posted to IDMS.
   c. How data is viewed in IDMS.
   d. Reports generated in IDMS.
   e. Alarms and notification through IDMS.
   f. How access is controlled to IDMS and by whom.

10. Transition Plan – to turn over the system to the follow on contractor.
    a. As-built instrumentation locations
    b. Instrument details, such as serial numbers, calibration factors, paper report of data collected during the course of this project, and summary of all repairs and/or replacements to instruments.
    c. Report on action levels.

1.09 CORRECTIVE ACTION PLAN

A. Details of actions to be taken in the case that settlement or lateral movement, strains, or groundwater drawdown exceed the Trigger or Maximum Levels indicated on the Contract Drawings.

B. Provide specific actions for the following facilities, including potential replacement of utilities if necessary:

1. 72-inch Diameter Ravenna Trunk Sewer
2. 54-inch Diameter Water Main in Montlake Blvd

C. Include operational changes to reduce the rate of soil or structural movements, strains in bracing, and groundwater drawdown.

1.10 WELL DECOMMISSIONING WORK PLAN

A. Submit at least 60 Days prior to beginning the decommissioning work.

B. At a minimum, include the following in the work plan:
   1. Schedule of activities.
   2. Methods and procedures of decommissioning.
   3. Equipment to be used.
   4. Driller's water well drilling license number and qualifications.
   5. Waste management procedures.
   6. Name, address, contact phone number for anticipated disposal facility.
   7. Health and Safety Plan and requirements. Include air monitoring, action levels, and decontamination procedures, in accordance with requirements of appropriate Specification Sections.
   8. Emergency and contingency procedures and measures.
   9. Copies of Notice of Intent to Decommission a Well.
   10. Variances, if any approved.

PART 2 - PRODUCTS

2.01 GENERAL

A. Verify all instruments and equipment are the manufacturer's standard products without modifications except those that may be noted below.

B. For vibrating wire instruments, ensure the manufacturer submit test data demonstrating that the sensor has been stable, within the accuracy requirements of this Section, for a period of not less than 5 years under laboratory conditions, when thermal effects have been considered. Instruments for which such stability data cannot be submitted are not to be considered "or equal".

C. Where model numbers are given in this Section, interpret them to represent models selected on the basis of past factory specifications and project experience demonstrating that the equipment will meet the specified performance objectives. Verify with the selected manufacturer that the designated model, or the updated version, or allowed equal, meets the design performance requirements described in this Section.

D. All instruments, except inclinometers and survey system instruments which cannot be readily automated shall be fully compatible with dataloggers and associated software described in this Section, without loss of accuracy or function.
E. Only use signal cables for instruments provided by the manufacturer of the associated instrument and suitable for the expected environment. Do not splice cables between the instruments and dataloggers.

F. All instruments and equipment shall be manufactured in the United States of America.

2.02 MATERIALS

A. Grout backfill mix for all instrumentation installations: Mixture of 94 pounds of portland cement, 25 pounds of bentonite, and 30 gallons of water.

B. Cement: Portland Cement, in accordance with Section 03 05 15, Portland Cement Concrete.

C. Concrete: Class 3000 A mix in accordance with Section 03 05 15, Portland Cement Concrete.

D. Epoxy Mortar: Two-component, 100 percent solids, 100 percent reactive compound suitable for use on dry or damp surfaces. Use Sikadur 32 Hi-Mod produced by Sika Chemical Corp., or approved equal.

E. Bentonite:
   1. Premium grade Wyoming sodium montmorillonite manufactured in accordance with API RP 13A.
   2. Bentonite pellets: Compressed Wyoming bentonite of pellet size 3/8 inch to 1/2 inch, Baroid Industrial Drilling Products Company or approved equal.

F. Controlled Density Fill (CDF): In accordance with [City of Seattle Standard Specifications for Road, Bridge and Municipal Construction].

G. Materials for Well Decommissioning:
   1. Obtain water from an approved, potable water source.
   2. Bentonite.
   3. Use high early strength, Type III Portland cement.

2.03 INCLINOMETERS

A. Inclinometer Probe:
   1. Slope Indicator Co. (Sinco) Model 50302500, Geokon Model 6000 or approved equal.
   2. Measurement Requirements:
      a. Resolution: 0.0001 feet per 2 feet
      b. Accuracy: within 0.025 feet per 100 feet
      c. Range: within 35 degrees from vertical

B. Inclinometer Cable:
   1. Slope Indicator Co. Model 50601000, Geokon Model 6000-4 or approved equal.
2. Steel core wire, Neoprene cable jacket, depth marks vulcanized to jacket every foot.

3. Constructed to prevent slippage between jacket and core.

4. Connectors as recommended by manufacturer.

5. Minimum length: 200 feet.

C. Readout unit: Slope Indicator Co. Model 50310900, Geokon Model GK-603 or approved equal.

D. Inclinometer Software:
   1. Computer software for uploading casing information to readout device, downloading instrument readings to computer, data reduction, and plotting. Use software that is compatible with the specified probe and read-out device.
   2. Software capable of plotting:
      a. Multiple profiles of the same casing on the same plot calculated from the bottom up or the top down.
      b. Real-Time-Displacement at selected depths.

E. Ancillary equipment: provide pulley assemblies compatible with casing and probe, and other accessories for a complete and functional system.

F. Casing
   1. Slope Indicator Co. Models 51101100 or 51150210, Geokon 6400 or approved equal.
   2. Material: Acrylonitrile/butadiene/styrene (ABS) with internal grooves at 90 degree intervals.
   3. Diameter: 2.75-inch Outer Diameter, 2.32-inch Inner Diameter.
   4. Spiral / misalignment: no more than 0.033 degree per foot
   5. Couplings: as provided by casing manufacturer.
   6. Casing cement (if used): As recommended by manufacturer for temperature and humidity conditions at the site.
   7. Top and bottom end caps: As provided by casing manufacturer.
   8. Ancillary equipment: Pop rivets, rivet gun, joint tape, pipe clamps, and other equipment as recommended by casing manufacturer for a complete and functional system.

G. Tremie Tube
   1. Continuous polyethylene or approved equal.
   3. Wall thickness sufficient to withstand external hydrostatic pressure and internal grout pressure.
H. Backfill: Grout backfill mix specified herein.
I. Protective Enclosure: As specified herein.

2.04 SURVEY SYSTEM

A. Surface Settlement Points: As shown on the Contract Drawings.

B. Structure Settlement and Soldier Pile Shoring Monitoring Points: As shown on the Contract Drawings, or use adhesive-backed targets, Leica Models #635-317 (20mm square), #635-318 (40 mm square), or #635-319 (60 mm square), or approved equal.

C. Utility Settlement Points: As shown on the Contract Drawings.

1. Fiberglass bar: Fibergrate Dynaform®, Tencom P626, or approved equal.
2. Epoxy Mortar: Compatible with fiberglass and utility materials, service life minimum 5 years under wet conditions.

D. Wall Survey Points: Adhesive-backed targets, Leica Models #635-317 (20mm square), #635-318 (40 mm square), or #635-319 (60 mm square), or approved equal.

E. Protective Enclosures: As specified herein.

F. System Accuracy Requirements

1. The accuracy requirements established in this Section apply to the final data, including the composite effects of reflectors, readout instruments, measurement methods, temperature, operator variability, and other contributing factors.
2. All accuracies in this Section have an associated confidence level of 90 percent.
3. Survey points used for monitoring ground surface settlement:
   a. Within 0.01 foot vertical
   b. Within 0.01 foot horizontal
4. Reflectors installed on temporary or permanent structures:
   a. Within 0.01 foot vertical
   b. Within 0.01 foot horizontal
5. Optical monitoring lines: 0.01 foot perpendicular to the line.

2.05 STRAIN GAGE SYSTEM

A. Furnish a strain gage system including weldable vibrating wire strain gages, thermistors, signal cables, read-out device, and surface mounted terminal enclosures, as manufactured by Slope Indicator Co., Geokon or approved equal.

B. Provide weldable vibrating wire strain gages with:

1. Maximum strain range of 3,000 microinches per inch.
2. Average sensitivity of one microinch per inch.
3. Temperature range of minus 40 to 150 degrees F.
4. Signal cable with four conductors, rubber insulated and shielded.
5. Service life minimum of three years under normal conditions.
6. Thermistors furnished integral to each strain gage.
7. Slope Indicator Co. Model 52602101 with strain gage sensor Model 52623000, or Geokon Model 4000, 4100 or 4150, or approved equal.

C. Provide waterproof signal cables and connectors in sufficient lengths and numbers for operation of the approved strain gages, as recommended by the manufacturer. Each signal cable shall be clearly labeled with a unique strain gage designation.

D. Provide protective conduit for the signal cables.

E. Provide steel protective covers over all strain gages. The protective covers shall be designed and mounted so as not to affect the operation of the gages, as recommended by the strain gage manufacturer.

F. Provide weatherproof enclosures for termination of signal cables with:
1. Hinged doors that provide rapid and convenient access, without unbolting and removing the entire enclosure.
2. Lockable and keyed alike, provide three sets of keys to Sound Transit.
3. Fitted with flanges, brackets, or other equipment appropriate for the associated type of mounting. Mounting equipment shall be welded or otherwise attached to the enclosure and shall not penetrate the protective enclosure via bolt holes or similar opening.
4. Standard fittings for conduit and cable entry.
5. Terminal board for individual cable connections.
6. Manual switch plates with connectors for the read-out device. Each strain gage designation shall be clearly marked at the switch position to which it was connected.
7. Model 57711600, as supplied by Slope Indicator Co., Model 4000-6 as supplied by Geokon for arc weldable strain gages, Model 4100-5 as supplied by Geokon for the 4100 strain gage, or approved equal.

2.06 PIEZOMETERS

A. Use piezometers of the vibrating wire type, Slope Indicator Co. Model 52611030, Geokon Model 4500S or approved equal.

B. Housing: stainless steel.

C. Use piezometers which include integral thermistors for temperature measurement.

D. Measurement requirements:
1. Resolution: within 0.025 percent of Full Scale
2. Accuracy: within 0.1 percent of Full Scale
3. Range: 100 feet head
E. Protective Enclosures: As specified herein, except with at least 12 inches internal diameter.

2.07 MULTI-POINT BOREHOLE EXTENSOMETER
A. Provide three to five position multiple point borehole extensometers to measure subsurface settlement. Use a reference head with an electric sensor with a total system accuracy not less than 0.1 inch.

B. Anchors and Rods:
1. Three to five mechanically or hydraulically operated anchors set at depths as indicated on the Contract Drawings. Use Slope Indicator Co. Model 51703952, Geokon Model A-5 or approved equal.
2. Non-corrosive rods individually sheathed in protective tubing.
3. Rod spacers to space and support rods.
4. All necessary couplings, caps, fittings, installation tools and accessories.

C. Electrical Reference Head:
1. Vibrating wire transducers, Slope Indicator Co. Model 52636325, Geokon Model 4450VW or approved equal. Provide thermistors for transducers.
2. Connect reference head to datalogger devices for remote reading as specified herein.
3. Capable of manual check on readings using a depth micrometer or similar device.
4. Provide a minimum range of up to 2 inches of heave and 6 inches of settlement.
5. Provide direct burial PVC jacketed-type cabling for remote readouts.

2.08 GEOPHONE
A. See Section 01 57 15, Temporary Construction Noise and Vibration Control, for Geophone requirements.

2.09 PORTABLE READOUT UNIT
A. Furnish one portable readout unit capable of reading all vibrating wire instruments described in this Section.

B. Slope Indicator Co. Model 52613500, Geokon Model GK-403 or approved equal.

C. Provide connector cables for all instruments to be read with the readout unit.

2.10 DATALOGGER
A. Capable of reading all vibrating wire instruments and other sensors associated with instruments described in this Section.

B. Slope Indicator Co. Model CR1000 Datalogger, Geokon Model 8002 LC-2/16 or approved equal, for monitoring multiple instruments at the Roosevelt and Brooklyn Stations.
C. Slope indicator Co. Models 52613310 or 5261400, Geokon Models 8002 LC-2 or 8002 LC-2/4, or approved equal, for single or four channel dataloggers, respectively, for borehole instrumentation.

D. Provide one single-channel datalogger for each piezometer installed.

E. Provide dataloggers for extensometer installations as follows:

1. Install dataloggers prior to the leading TBM advancing to within 500 feet of the piezometer and extensometer locations.
2. Do not remove dataloggers until the trailing TBM has moved at least 2500 feet past the piezometer and extensometer locations.
3. Dataloggers can be installed in a staggered fashion as the tunnels advance.
4. Install dataloggers one week prior to cross passage construction for extensometers located within 200 feet of a cross passage.
5. Do not remove dataloggers until 1 month after cross passage construction has been completed.
6. All other readings can be taken using a portable readout unit in lieu of using dataloggers.

F. Complete with input, output, signal conditioning, communications, and other hardware for a complete and functional system, including but not limited to:

1. Multiplexers
2. Local input/output connection for laptop computer
3. Telephone modem or wireless connection.

G. Software: Capable of comparing the output of each sensor, in engineering units, against user-selected alarm limits, and electronically relaying hourly logged readings to the Contractor’s and Sound Transit’s offices. The alarm systems shall also have 24 hour connection to two pagers, to be assigned to designated representatives of the Contractor and Sound Transit, respectively.

H. Mount the datalogger in a protective enclosure as specified herein that will accommodate each manufacturer’s enclosures for components of the system.

I. Provide a continuous, adequate power source for the data logger in accordance with the manufacturer’s recommendations.

2.11 INSTRUMENTATION DATA MANAGEMENT SYSTEM

A. Capable of storing and disseminating all vibrating wire instruments and other sensors associated with instruments described in this Section.

B. Automated processing of the instrumentation data to convert readings into meaningful engineering units.

C. Checks for action levels for each instrument and alerts the Resident Engineer and Contractor in the event an action level is reached.

D. Displays graphs of instrumentation data.
E. Generates reports of instrumentation data.
F. Access to the information is controlled.
G. Argus system provided by SINCO, or approved equal.

2.12 PROTECTIVE ENCLOSURES

A. Provide protective enclosures with the following features, and as indicated on the Contract Drawings:
   1. Bolted lids.
   2. Painted or otherwise protected from weather, and waterproof to prevent the ingress of water into the enclosure.
   3. With flanges, brackets, or other equipment appropriate for the associated type of mounting. Weld or otherwise attach mounting equipment to the enclosure and do not penetrate the protective enclosure (i.e., no bolt holes).
   4. A minimum of 3-inch clearance all around the enclosed instrument, or as indicated on the Contract Drawings, or as required by product manufacturers for specific instruments.
   5. Materials: Steel or cast iron.

B. Ensure conduit for signal cable penetrates the wall of the enclosure using standard fittings to provide continuous protection for the cable.

C. Ensure signal cables not enclosed in conduit penetrate the wall of the enclosure through standard weather-proof flexible compression (grommet) fittings.

D. For enclosures subjected to vehicular traffic, mount the enclosure flush with the ground surface, and design for H-20 AASHTO loading.

2.13 IDENTIFICATION TAGS

A. Provide each instrument with a stainless steel indented name tag designating the instrument number, as shown on the Instrumentation Schedule on the Contract Drawings.

B. Indent character a minimum of 3/8 inch high, indented with the indenter marker press provided by name plate manufacturer.

C. Where possible without affecting instrument function, attach name tags directly to instrument using heavy black (UV-resistant) nylon tie-wrap.

D. For name tags that cannot be attached directly to the associated instrument, mount on the associated structure or enclosure as close as practicable to allow convenient, unambiguous reading. Mount using epoxy or other adhesive as recommended by name tag manufacturer. Use a mounting method that is approved by Sound Transit prior to use.

E. For each strain gage, provide an alpha-numeric identifier, approved by Sound Transit at each strain gage location. The identifier shall be stenciled characters two inches high using paint, and permanently marked near the end of the corresponding strain gage signal cable and at the final switch position to which it is connected.
PART 3 - EXECUTION

3.01 GENERAL

A. Be responsible for safety during all instrument installation and monitoring activities. Conduct all instrumentation activities in accordance with applicable Federal, State, and local regulations and all project-specific health and safety plans. Where conflicting requirements are encountered, the most stringent shall apply.

B. Characterize and dispose of all waste generated by work in accordance with applicable regulations and these Specifications.

C. Allow time for and include all instrumentation installation, monitoring, baseline readings, and associated work in the construction schedule.

D. Install all instrumentation complete and functional to the satisfaction of Sound Transit. Replace unsatisfactory instrumentation or associated equipment at own expense.

E. Be responsible for locating utilities before installing instruments that involve digging and drilling. Damage to utilities, structures, or other facilities shall be the Contractor’s sole responsibility.

F. Provide access to all instrument locations and facilitate occasional monitoring of other instrumentation by Sound Transit by temporarily stopping or interrupting certain portions of the work, as may be required as not to delay the work unnecessarily. Schedule and perform work in a manner so as not to delay monitoring by Sound Transit.

G. Upon direction from Sound Transit, remove and dispose of instruments. Do not remove instruments prior to receiving written direction from Sound Transit. Do not decommission instruments installed in boreholes until all excavation and support is substantially complete within 500 feet, or readings have stabilized.

H. Leave instruments that are no longer accessible in place. Cut signal cables from such instruments flush with the structure or ground surface, remove protective enclosures and at least the upper six inches of casing, and backfill conduits with grout backfill mix as specified herein.

I. Fill holes drilled in concrete structures with epoxy mortar to match surrounding concrete.

J. Remove name tags attached to concrete structures and all associated adhesive.

K. Backfill holes from protective enclosure mountings and similar installations with CDF to prevent future settlement.

L. Prepare and submit the instrumentation borehole and well abandonment Start Cards, as well as a copy to the Washington State Department of Ecology. Submit a copy of approved variances.

M. Notify the Resident Engineer at least 7 Days prior to the start of work.

N. Prepare and submit well abandonment logs to the Resident Engineer.

O. Coordinate activities with other components of these Specifications.
3.02 INSTALLATION SCHEDULE

A. Install all instruments and make operational, with stable baseline readings, a minimum of four weeks prior to the start of shoring, excavating, tunneling, or other work requiring monitoring unless specified otherwise.

B. Obtain baseline readings prior to the start of associated construction activities, as specified herein. Notify Sound Transit when instruments are ready for baseline readings.

C. Verify baseline readings agree to within the accuracy of the instrument or as approved by Sound Transit.

D. Do not begin construction activities without written approval from Sound Transit.

E. For strain gages, install on the corresponding bracing member after lifting and placing, and prior to excavating more than three feet below centerline of struts. Take zero-load readings before excavating more than three feet below centerline of struts.

F. For soldier pile, wall survey and contractor designed temporary shoring monitoring points, install on the corresponding shoring element prior to excavating more than three feet below the instrument.

G. Portable readout units may be used for testing instrument function prior to connection with datalogger and at other times as necessary. However, implement fully automated (datalogger) reading function prior to the start of construction of the associated feature, or as specified herein.

H. Provide surveyed location of each instrument within five working days after installation has been completed.

3.03 PROTECTION

A. Provide at installation protective enclosures, plates, cable conduit, and other equipment as required to protect the instrumentation system from damage during construction.

B. Be responsible at own expense for repairing or replacing instruments or associated components that are damaged during construction, as directed by Sound Transit.

C. Route all signal cables to the corresponding readout station inside of protective conduit.

3.04 INSTALLATION PROCEDURES

A. General

1. Unless otherwise specified, install all instruments in accordance with the manufacturer’s recommendations and requirements. Manufacturer’s recommendations are included as a part of these Specifications by reference, and are applicable, regardless of whether a particular recommendation is explicitly stated in this Section or not.

2. Adhere to manufacturer’s requirements for alignment of instruments.

3. Follow manufacturer’s precautions on handling. Many of these instruments are susceptible to damage if not handled properly.

4. For instruments installed in boreholes, perform the following:
a. Obtain soil samples at 5-foot vertical intervals in conjunction with the Standard Penetration Test (SPT).

b. Preserve soil samples in airtight jars or plastic bags and submit to the Resident Engineer. Include the following information on the sample container in permanent ink: instrument designation, date, sample number, sample depth and sample SPT value.

c. Provide the following information on boring logs for each instrument installation: instrument designation, date, logger's name, sample numbers, sample depths, SPT values, and descriptions of soil samples in accordance with the Unified Soil Classification System (USCS).

5. Monitor surface settlement and structure settlement points located within 1000 feet of Brooklyn and Roosevelt Stations for both lateral and vertical movements. Monitor all other surface settlement and structure settlement points for vertical movement only.

B. Inclinometers

1. Install inclinometer casings to the depths listed on the Contract Drawings.

2. Install inclinometer such that the bottom of casing is within 1 degree of vertical, referenced to the top of the casing at the ground surface or top of slurry wall.

3. For cemented casing, join casing using casing cement followed by installation of pipe rivets at 90-degree intervals around casing for each pipe section (total eight rivets). Join other types of casing as recommended by casing manufacturer.

4. Tape all joints and install bottom cap to prevent grout entry.

5. Attach tremie tube to outside of casing using wire or tape. Align end of the tube to be even with bottom of casing, to allow filling of borehole from the bottom up. Block bottom of the tremie tube, to force grout through side ports.

6. Orient inclinometer casing so that the orthogonal grooves are positioned parallel and perpendicular to the expected direction of movement, typically perpendicular to the long axis of the excavation, tunnel, or retaining wall, as approved by the Resident Engineer. Temporarily close top of casing to prevent entry of foreign material.

7. Fill casing with water and anchor casing as required to prevent it from floating out of the borehole during installation.

8. Fill the annular void between the drill hole and the inclinometer casing with backfill grout in one continuous stage, pumped through the tremie tube. Collect minimum 3-inch diameter jar sample of grout at time of installation to verify setting time.

9. Do not install protective cap or otherwise disturb inclinometer for a minimum of 24 hours after installation, or until backfill grout has set, as approved by the Resident Engineer.

10. Install protective enclosure concentric with inclinometer casing to a depth of at least 3-feet below ground surface. Center inclinometer casing inside the protective enclosure, and fill annulus with grout to 12-inches below top of inclinometer casing. Backfill around outside of casing to ground surface with concrete of CDF to ensure that casing will remain in position.
C. Utility Settlement Points

1. Remove pavement over utility by coring or cutting. Minimize area of pavement removal.
2. Excavate to top of utility using vacuum truck, hand auger, or other suitable method. Do not damage utility.
3. Install temporary casing, trench box, or similar protective equipment as required to provide safe support and access for installation of settlement point.
4. Clean top surface of utility as recommended by epoxy manufacturer to ensure adequate bond with fiberglass bar.
5. Install bar and pipe riser as indicated on Contract Drawings. Maintain centralized alignment throughout installation. Do not allow bar to contact the inside of the riser pipe.
6. Install protective enclosure at pavement surface to accommodate traffic and prevent vandalism or other disturbance of measurement point.

D. Strain Gages

1. Install strain gages in accordance with the manufacturer’s printed installation instructions.
2. Install all strain gages on the corresponding bracing members with steel covers, and stenciled gage identification numbers next to the gages. Mark corresponding identification numbers on each signal cable.
3. Anchor protective conduit at five-foot maximum intervals.
4. Install terminal enclosures adjacent to each section of instrumented struts, in protected location, and with convenient access for Sound Transit.
5. Connections to datalogger shall be made in accordance with the strain gage manufacturer’s recommendations.

E. Piezometers

1. Support all downhole components during installation to prevent damage.
2. Measure the depth of the sensor by measuring the length of sensor and signal cable in the casing, to the nearest 0.1 foot.
3. Backfill around piezometer and boring with backfill grout mix as specified herein.
4. Provide protective enclosure as specified herein.

F. Multi-Point Borehole Extensometer:

1. Drill borings for the extensometer of a diameter as recommended by the instrument manufacturer, to provide a borehole in which to install the anchors and rods.
2. Bundle and install extensometer anchors in one installation at the depths indicated on the Contract Drawings.
3. Install electrical reference head, and hook up to datalogger.
4. Provide protective enclosure as specified herein.

G. Soldier Pile Shoring Monitoring:
1. For Soldier pile shoring system: Install a structure settlement point on the top of every other soldier pile.

H. Contractor Designed Temporary Shoring Monitoring:
1. For temporary soldier pile shoring systems: install a structure settlement point on the top of every other soldier pile.
2. For other temporary shoring systems, including soil nail walls, install structure settlement points on the top of the wall at intervals of no more than 25 feet.

I. Wall Survey Points:
1. For owner designed shoring: As indicated on the Contract Drawings.
2. For soldier pile shoring systems: install a structure settlement point on the top of every other soldier pile.

3.05 MAINTENANCE
A. Maintain all instrumentation in accordance with manufacturer’s recommended procedures and schedule, or as directed by Sound Transit, including instrumentation installed during previous contracts.

B. Replace damaged installations which are the result of the Contractor’s operations immediately, including instrumentation installed during previous contracts.

C. Report all damaged or non-functional instrumentation to the Resident Engineer immediately.

3.06 INSTRUMENT MONITORING
A. General
1. Perform monitoring activities for all instrumentation specified herein. Reference the Contract Drawings and requirements specified herein for monitoring frequency for each instrument.
2. Provide all necessary assistance in the form of labor and equipment to enable Sound Transit to access those instruments, which Sound Transit will occasionally monitor. These may include, but are not limited to, removing obstacles or obstructions and providing access to elevated instruments.
3. When instruments detect sudden changes in measured properties, values that exceed Trigger or Maximum Level values, or other notable conditions, take additional readings as required. Coordinate monitoring activities for extensometers at cross-passages with in-tunnel instrumentation in accordance with Section 31 09 13.50, Tunnel Instrumentation and Monitoring.

B. Baseline Readings:
1. Obtain baseline readings from all instrumentation.
2. Provide baseline readings by conducting three separate and complete sets of readings on each instrument at least one day apart each. Readings will be taken with sufficient accuracy to produce similar results in each of the three readings.

3. Submit electronic copies using files in the latest version of Microsoft Excel and/or specialized software specified herein associated with the instruments described in this Section and paper copies of the data from readings of monitoring instruments and settlement points taken as indicated herein, to Sound Transit within 12 hours after the readings are taken.

C. Action Levels:

1. Action levels are as defined herein, and values for each instrument are indicated on the Contract Drawings or specified herein. Levels indicated are the following, for each type of instrumentation:
   a. Surface settlement points, structure settlement points, soldier pile shoring monitoring points and contractor designed temporary shoring monitoring points, wall survey points: Total movements.
   b. Extensometers, near surface settlement points, and utility settlement points: Vertical movements.
   c. Inclinometers: Horizontal movements.
   d. Piezometers and observations wells: Groundwater drawdowns.
   e. Geophones: Velocity.
   f. Strain gages: Strain.

2. When instrumentation data indicates strains, or horizontal or vertical movements in the ground or on structures or existing buildings, buried utilities or surfaces, exceed the action levels, implement the following procedures specified herein.

3. Exceeding Action Levels:
   a. Trigger Level:
      1) Verify measurement and notify the Resident Engineer immediately after obtaining measurements that exceed the Trigger Level for that instrument.
      2) Double the frequency of future monitoring of that instrument and adjacent instruments until movements have stabilized.
      3) Implement procedures in order to limit further movements.
      4) For the following utilities, perform leak tests. Coordinate testing and leak repairs with [Seattle Public Utilities (SPU)].
      5) Perform leak tests for the cast iron pipe water mains.
   b. Maximum Level:
      1) Verify measurements and notify the Resident Engineer immediately after obtaining measurements that exceed the Maximum Level for that instrument.
2) For all values exceeding those indicated, and depending on conditions, Sound Transit may suspend excavation and associated activities at that location, and require the Contractor to submit alternative proposals for minimizing further movements.

3) If work is suspended, obtain approval from Sound Transit prior to restarting excavation at that location, under approved procedures.

4. Monitor geotechnical instruments continuously until ground and/or the structure have been stabilized. The Resident Engineer has the discretion to reduce the frequency of monitoring if readings stabilize.

D. Replacement Levels

1. Replace utilities between points of zero settlement along the utilities if the following movement levels are exceeded:
   a. TBD at 90%

2. For sewer and storm drains: Replace any sagged sections and match existing slopes.

3. Coordinate work with the appropriate utility companies.

E. Soldier Pile Shoring, Contractor Designed Temporary Shoring, and Wall Survey Point Monitoring

1. Conduct optical surveys for vertical and horizontal movements.

2. Take readings a minimum of twice weekly during mass excavation.

3. Take readings a minimum of once per week after completion of mass excavation and after wall movements have stabilized. Continue readings on this schedule until directed to modify or cease readings by Resident Engineer.

4. Action levels: Follow procedures specified herein for other instrumentation if the following levels are exceeded.
   a. Trigger Level: 0.6 inch.
   b. Maximum Level: 1.0 inch.

F. Strain Gage Monitoring

1. Perform monitoring as shown on the Contract Drawings. Monitor gages once per week during construction activities.

2. Action levels: Follow procedures specified herein for other instrumentation if the following levels are exceeded.
   a. Trigger Level: 500 microstrain.
   b. Maximum Level: 700 microstrain.
3.07 WELL DECOMMISSIONING

A. Decommission Wells in accordance with the regulatory requirements and/or approved variance. Do not decommission wells without approval from the Resident Engineer.

B. Decommission wells per the following schedules, as indicated on the Contract Drawings for each well:

1. Schedule A: Decommission well at least 14 Days prior to performing any construction within 250 feet of the well.

2. Schedule B: Decommission after construction, but prior to final Substantial Completion.

3. Schedule C: Do not decommission well. Well will be decommissioned as part of a subsequent contract.

4. Schedule D: Decommission well at any time.

C. Contain and containerize all ground water flowing out of the wells during decommissioning. Store ground water in 55-gallon drums or a temporary holding tank.

D. Restore the surface to conditions to match the surrounding ground surface.

3.08 WASTE MANAGEMENT

A. Collect and properly dispose of all waste generated during well abandonment.

B. Handle and dispose of groundwater collected in accordance with Section 31 23 19, Dewatering.

C. Handle and dispose of well material and soil generated from the abandonment procedure as solid waste.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 31 11 00

CLEARING AND GRUBBING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for clearing, grubbing, and disposing of vegetation, including bushes, brush, trees, stumps, roots, rubbish, refuse, trash, and debris within the indicated site limits.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 35 93, Archaeological Finds.
2. Section 01 56 39, Temporary Tree and Plant Protection.
3. Section 02 41 00, Demolition.
4. Section 31 20 00, Earth Moving.

PART 2 - PRODUCTS

2.01 MATERIALS AND EQUIPMENT

A. Furnish materials, tools, equipment, facilities, and services as required for performing site clearing and grubbing.

PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to clearing and grubbing operations, notify the Resident Engineer at least one week in advance of planned activities and make work sites available to Sound Transit’s Archaeologist for observation. Notify the Resident Engineer in the event artifacts are discovered during clearing and grubbing work. Comply with the requirements of Section 01 35 93, Archeological Finds.

B. Dispose of cleared, grubbed, and removed material away from the site. Burying and burning of materials at the site is not permitted. Stockpile salvaged material in a secured location.

C. Clear and restore areas used for the Contractor’s convenience; restore areas to original condition providing mulching, seeding, and planting as required.

D. Protect survey markers and monuments, existing improvements, existing observation wells and piezometers, and adjacent properties from removal and damage.
E. Protect all trees, lawns, and planted areas that are not in direct conflict with the work shown on the Contract Drawings. Restore all on-surface disturbed areas to a condition satisfactory to the Resident Engineer.

F. Review with the Resident Engineer the location, limits, and methods to be used before clearing work. Perform clearing and grubbing in compliance with all local, state, and federal laws and requirements pertaining to clearing and grubbing.

G. Care of Existing Trees: Protect trees and plants indicated in the Contract Documents to remain and to be preserved as specified in Section 01 56 39, Temporary Tree and Plant Protection.

H. Tree Salvage:

1. Prior to tree removal, attend an on-site meeting with the Resident Engineer to review requirements for tree salvage for each tree.

2. For tree salvage, de-limb all trees and cut into 14 ft sections with a minimum diameter of 12 inches.

3. Clearly label each log with the tree tag number in weatherproof ink or paint.

4. Salvage the trees in the following list:

<table>
<thead>
<tr>
<th>Tag Number</th>
<th>Common Name</th>
<th>Tag Number</th>
<th>Common Name</th>
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3.02 CLEARING AND GRUBBING

A. Clear the site within the limits indicated on the Contract Drawings and remove cleared materials and debris from the site. Unless otherwise indicated, clearing and grubbing includes removal of all 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. In embankment areas, 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 large roots may be removed concurrently with excavation.

1. Where the work includes requirements for wood chip mulch, acceptable material from clearing and grubbing activities may be used to produce such mulch.

D. Demolition/Removal

1. Coordinate the work of this Section with the work of Section 02 41 00, Demolition, as required to remove existing pavements, curbs, structures, and site improvements which interfere with new construction and where demolition is not indicated.

E. Disposal of Cleared Vegetation, Grubbed Material and Waste

1. Dispose of in a safe, acceptable manner, in accordance with applicable laws and ordinances.
   a. Do not bury or burn trash and debris on the site.
   b. Remove cleared vegetation, grubbed material and waste from the site at frequent intervals so that its presence will not delay the progress of the Work or cause hazardous conditions for workers and the public.
   c. Removed materials, waste, trash, and debris shall become the property of the Contractor. Remove such materials from the Site and dispose of in a legal manner. It is the responsibility of the Contractor to locate disposal sites and determine length of haul route.

2. Backfill: Backfill excavations resulting from work under this Section in accordance with applicable requirements of Section 31 20 00, Earth Moving.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for earthwork including: excavation and placement of compacted fill, subgrade and foundation preparation; subsurface extraction of miscellaneous structures and facilities indicated or required to be removed; and finish grading.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 35 93, Archaeological Finds
2. Section 01 56 39, Temporary Tree and Plant Protection
3. Section 01 57 13, Temporary Erosion and Sediment Control
4. Section 01 57 19, Temporary Environmental Project Control
5. Section 01 71 23, Field Engineering
6. Section 01 74 00, Cleaning and Waste Management
7. Section 02 41 00, Demolition
8. Section 31 11 00, Clearing and Grubbing
9. Section 31 23 19, Dewatering
10. Section 31 23 33, Trenching and Backfilling
11. Section 31 50 00, Excavation Support and Protection
12. Section 32 11 23, Aggregate Base Courses
13. Section 33 01 00, Operation and Maintenance of Utilities

1.02 REFERENCES

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

c. ASTM D1557 Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort

d. ASTM D2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

e. ASTM D2487 Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

f. ASTM D2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

g. ASTM D2974 Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils

h. ASTM D3017 Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)

i. ASTM D4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

2. Washington Administrative Code (WAC)

a. WAC 296-155 Part N, Safety Standards for Construction Work, Excavation, Trenching and Shoring

3. Washington State Department of Transportation (WSDOT)

a. Standard Specifications for Road, Bridge, and Municipal Construction

4. City of Seattle (COS)

a. Standard Plans for Municipal Construction

b. Standard Specifications for Road, Bridge, and Municipal Construction

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Material source, and all tests and certifications necessary to approve material, including moisture/density relation test results. If on-site material is proposed for use as any of the materials specified in construction, provide test results certifying suitability of said material. Sampling and tests for on-site material suitability shall be performed at a minimum of every 200 cubic yards of material, and shall also be performed randomly at the request of the Resident Engineer.

1.04 QUALITY ASSURANCE

A. Quality Plan: Conform to Section 01 45 00, Quality Control, covering all earthwork operations and the field quality control to be performed.

B. Quality Control: Provide quality control to ensure compliance with specified requirements.

C. Tests: Engage the services of an approved independent soils testing laboratory to perform tests.

D. Tolerances:
1. Construct finished surfaces to plus or minus 1/2 inch of the elevations indicated.

2. Maintain the moisture content of fill material as it is being placed within 2 percent of the recommended moisture content of the material.

1.05 CLASSIFICATION OF EARTHWORK

A. For specification purposes, earthwork shall be classified as follows:

1. Excavation-Common: All excavation involved in grading and construction of the station structure, parking areas, landscaped areas, walkways, roads, driveways, and connections thereto; and all other excavation classified or indicated as common excavation.

2. Subsurface Extraction: Includes removal of abandoned utilities, tanks, walls, foundations, and other miscellaneous subsurface man-made structures that interfere with new construction and are designated to be removed, and the cleaning of such items if they are indicated to be salvaged. Removal of such obstructions at or above grade is specified in Section 02 41 00, Demolition.

3. Structure Backfill: Structure backfill includes furnishing structural fill material, and placing and compacting structural fill material around structures to the lines and grades indicated. Structural fill material includes borrow excavation and material when required.

4. Fill for Raising Grade: Includes raising of subgrade or grade to indicated elevation with structural fill, including moisture-conditioning and compaction of placed fill material. Structural fill material includes borrow excavation and material when required.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Fill and Backfill Materials – General Requirements

1. For material used for fill and backfill construction use inert, inorganic soil, free from deleterious substances and of such quality that it will compact thoroughly without the presence of voids when watered and rolled. (Inorganic soil is defined as soil containing less than two percent by weight of organic material when tested in accordance with ASTM D2974.) Excavated on-site material will be considered suitable for fill, backfill, and embankment construction if it is free from organic matter and other deleterious substances and conforms to the requirements specified herein.

2. When excavated material is suitable for fill, backfill, and embankment construction, condition material for reuse and properly stockpile for later filling and backfilling operations. Conditioning includes spreading material in layers not to exceed 8 inches and raking free of debris and rubble. Remove rocks exceeding 6 inches in largest dimension and deleterious material from the site and disposed of as specified herein under Disposal of Surplus Material.

3. Where conditions require the importing of fill or backfill material, use an inert soil or soil-rock material free of organic matter and meeting or exceeding the minimum requirements specified herein for the location.

4. All material to be used for filling and backfilling construction requires written approval of the Resident Engineer.
B. Structural Fill

1. Select from suitable on-site excavated material meeting the requirements of Section 9-03.14(1), Gravel Borrow of the WSDOT Standard Specifications; otherwise, import material conforming to Section 9-03.14(1), Gravel Borrow of the WSDOT Standard Specifications.

2. Material containing peat, muck, swampland, buried logs or stumps, or other contamination making the material not fit for embankment base is deemed unsuitable.

C. Non-structural Fill

1. Select from suitable on-site excavated material as determined by the Resident Engineer; otherwise, the Contractor shall import material conforming to Section 9-03.14(3), Common Borrow of the WSDOT Standard Specifications. Material containing wood, organic waste, coal, charcoal, or any other extraneous or objectionable material is deemed unsuitable.

D. Backfill where not otherwise indicated: Gravel Borrow, Mineral Aggregate Type 17 in accordance with COS Standard Specifications Section 9-03.14.

E. Structural backfill Controlled Density Fill (CDF) in accordance with WSDOT Standard Specification Section 2-09.3(1)E.

F. Materials for Trenching, Bedding, and Backfilling of utilities in accordance with Section 31 23 33, Trenching and Backfilling.

G. 3-Way Topsoil: The 3-way topsoil shall have a composition as follows: 60 percent sandy loam, 20-30 percent organic amendment and 10-15 percent peat with 100 percent passing through a 1/2 inch screen, as supplied by Pacific Topsoils, Inc (425) 337-2700, or approved equal.

H. Aggregates for pavement bases: Section 32 11 23, Aggregate Base Courses.

I. Aggregates including but not limited to the following categories are to comply with the City of Seattle Standard Specifications Section 9-03:
   a. Roadway Ballast
   b. Crushed Surfacing
   c. Gravel Backfill for Walls
   d. Pit Run Sand, Washed Sand
   e. Pea Gravel: Mineral Aggregate Type 9

2.02 SOURCE QUALITY CONTROL

A. Verify that fill, and backfill, materials proposed to be used in the work are tested in the Independent Testing Laboratory for compliance with WSDOT Standard Specification Section 9-03.20, COS Standard Specification Section 9-03.15 and as follows:


5. Percentage of Wear: ASTM C131 or C535 as applicable.

B. Where classification of soils is necessary to meet specified requirements, perform laboratory tests in accordance with ASTM D2487.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Staking and Grading
1. Lay out the work, establish all necessary markers, bench marks, grading stakes, and other stakes as required, in accordance with the requirements specified in section 01 71 23, Field Engineering.

B. Existing Utilities
1. Verify on site the location and depth (elevation) of all existing utilities and services before performing excavation work. Refer to Section 33 01 00, Operation and Maintenance of Utilities, for additional requirements. When excavating within 3 feet of an active utility line, perform excavation by hand.
2. Remove abandoned utilities or utilities indicated to be abandoned or removed encountered in the progress of excavating and plug ends.
3. Immediately report the discovery of active utility lines which are not indicated in the Contract Documents to the Resident Engineer and utility owners involved. Allow 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. Erosion Protection: Refer to Section 01 57 13, Temporary Erosion and Sediment Control.
B. Clear and Grub areas indicated on the Contract Drawings prior to earth moving operations in those areas. Refer to Section 31 11 00, Clearing and Grubbing.
C. Perform demolition in accordance with Section 02 41 00, Demolition, prior to earth moving operations in those areas.
D. See Section 01 56 39, Temporary Tree and Plant Protection, for Temporary Tree and Plant Protection requirements.
E. Comply with the requirements of Section 01 35 93, Archaeological Finds.

3.03 CONSTRUCTION

A. Earthwork General Requirements
1. Dust Control: Refer to Section 01 57 19, Temporary Environmental Controls.
2. Erosion Protection: Prevent erosion of the site at all times. Refer to Section 01 57 13, Temporary Erosion and Sediment Control.
3. Construction Traffic: Disperse travel paths of traffic and construction equipment over entire width of compacted surfaces so as to aid in obtaining uniform compaction. Protect exposed soil layers with high moisture content from excessive wheel loads.

4. On-Site Excavation or Borrow Pits: Do not excavate or remove any material from the project site or right-of-way which is not within the designated excavation, as indicated by the slope and grade lines, without written authorization from the Resident Engineer.

5. Stockpiling of Fill and Backfill Material:
   a. Excavate and separately stockpile suitable fill and backfill material, segregated by type, during the progress of the excavation work. Save sufficient suitable excavated material, if available, for later filling, backfilling, and embankment construction.
   b. Establish excavated material stockpiles on site only in locations where they will not interfere with the progress of the work. It is the responsibility of the Contractor to establish stockpiling offsite, if necessary.

6. Disposal of Surplus Material:
   a. Excess earth materials, unsuitable materials, and debris shall become the property of the Contractor. Remove material from the site and dispose it in accordance with Section 01 74 00, Cleaning and Waste Management.
   b. Comply with the WSDOT Standard Specification Section 2-03.3(7) and its referenced sections.
   c. The Contractor is responsible for locating an approved disposal site and haul route.

7. Maintenance of Excavations, Slopes, and Embankments:
   a. Excavate and remove material outside the limits of the excavation that is unstable and constitutes potential slides and material that comes into excavations for any reason including from the driving of piles.
   b. Maintain slopes and embankments until substantial completion and acceptance of the work. Promptly repair slides, slipouts, washouts, settlements, and subsidences that occur for any reason, and refinish the slope or embankment to the indicated lines and grades.
   c. Refer also to Section 31 50 00, Excavation and Support Protection, for requirements.

B. Subsurface Extraction

1. Remove subsurface facilities and obstructions to the extent indicated.

2. When subsurface facilities are encountered during excavation that interfere with new construction, and such facilities are not indicated, notify the Resident Engineer promptly for corrective determination.

C. Dewatering

1. Dewater excavation as specified in Section 31 23 19, Dewatering.
2. Prevent surface water and subsurface or ground water from flowing into excavations and from flooding project site and surrounding areas.

3. Provide and maintain pumps, sumps, suction and discharge lines, and other dewatering system components necessary to convey water away from excavations.

4. Establish and maintain temporary drainage ditches and other diversions outside excavation to convey water. Do not use trench excavations as temporary drainage ditches.

D. Moisture Control

1. Initiate stormwater runoff control measures to intercept and convey stormwater away from the site. Initiate dewatering measures to eliminate any standing water.

2. Where subgrade or layer of soil material must be moisture conditioned before compaction because it is too dry, uniformly apply water to surface.

3. Remove and replace, or scarify and air dry soil material that is too wet to permit compaction to specified density.

4. Soil material removed because it is too wet to permit compaction may be stockpiled or spread and allowed to dry. Assist drying by discing, harrowing, or pulverizing until moisture content is reduced to a satisfactory value.

E. Excavation

1. General Excavation Requirements:
   a. Perform excavation as indicated and required for concrete footings, foundations, retaining walls, exterior paving, floor slabs, concrete walks, and for site levels and grading, and provide shoring, bracing, underpinning, cribbing, pumping, and planking as required.
   b. Comply with applicable requirements of WAC 296-155 Part N.
   c. Trenching for utilities: Section 31 23 33, Trenching and Backfilling.
   d. Excavate the bottoms of excavations to be level, firm, undisturbed earth, clean and free from loose material, debris, and foreign matter.
   e. Excavate to the lines and grades indicated on the Contract Drawings.
   f. Support and maintain excavations by providing structural support of earth walls as specified in Section 31 50 00, Excavation Support and Protection, so that sides are stable and will not move. Excavations may be maintained by sloping cut faces where space permits, if calculations sealed and signed by a civil or structural engineer currently registered in the State of Washington, show that the slopes are safe. Ensure calculations consider all existing conditions, including adjacent traffic, construction loading, and other local effects.
   g. Keep trenching widths to a minimum. Allow for adequate working space for installing forms and as required for safety systems for within the limits of excavations.
h. Remove unstable bottom material. Remove large stones, debris, and compressible soils from excavation bottoms to a minimum depth of 12 inches.

i. Except as otherwise indicated, preserve the material below and beyond the lines of excavations. Where an excavation is carried below the indicated grade, backfill with structural fill to the indicated grades. Compact as described in Article 3.03.1, herein.

j. Place excavated material at a sufficient distance from edge of excavation so as not to cause cave-ins or bank slides, but in no case closer than 3 feet from the edge of excavations.

k. Payment will not be given for over-excavation caused by the Contractor’s negligence or convenience.

F. Backfilling

1. Backfill for utility trenches as specified in Section 31 23 33, Trenching and Backfilling.

2. Use materials removed from site excavations if such material meets specified requirements.

3. Backfilling is required around all substructures. Fill holes, pits, and other voids with structural fill and provide compaction in accordance with Article 3.03.1.

4. Allowable thickness of fill lifts depends on the material type and compaction equipment used. Place backfill in layers not to exceed eight inches of loose material for materials to be compacted by heavy equipment, and not more than four inches of loose depth for material compacted by hand-operated tampers.

5. Place backfill material in such manner that unbalanced horizontal loads will not be applied to a newly-placed structure or portion of structure, utility, or pipeline. Do not backfill around portions of structures requiring backfill on only one side or on less than all sides, until the concrete has reached the specified 28-day strength to withstand the earth pressures on structures.

G. Subgrade for Surfacing

1. Comply with WSDOT Standard Specification Section 2-06.3 for preparation of subgrade for roadbed surfacing including provisions for subgrade stabilization when the subgrade does not meet required density and subgrade maintenance and protection.

H. Finish Grading

1. Finish grade all areas to elevations and grades indicated within the specified tolerance.

2. In landscape areas where utility trenching or grading activities occurred, grade to the depth required below finished grade to allow placement of topsoil and/or mulch up to finished grade indicated in the Contract Drawings.

I. Compaction

1. Before compaction, moisten or aerate each layer as necessary to provide the optimum moisture content.
2. **Compaction Density:** Compact each layer of embankment, fill, and backfill material to not less than the indicated or specified compaction. Required compactions are defined as Class I and Class II, as follows:
   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. **Required Compactions:**
   a. **Embankment or Fill where the Surface will be Bearing Foundation:** Class II for full depth. Where embankment construction exceeds 5 feet in depth, provide minimum Class I compaction below the top 2.5 feet.

4. **Fill Below Pavements:** Class II for full depth. Where fill exceeds 3 feet in depth, provide minimum Class I compaction below the top 3 feet.

5. **Backfill around Structures:** Class I under top 12 inches; Class II for top 12 inches.

6. **Cut-and-Cover Backfill:** Class I to 36 inches above utility; Class II for balance, with a minimum of Class II for top 12 inches.

7. **Original Ground or Cut Subgrade:** Except where original ground or cut subgrade, or fill less than 1 foot thick, will be subgrade or bearing foundation, scarify the surfaces and provide Class II compaction for at least 8 inches in depth. Include the following additional requirements:
   a. Provide Class II compaction for original ground when such original ground is within 2.5 feet of finished pavement grade, for full width of pavement plus 3 feet on each side thereof.
   b. Provide Class II compaction for top 6 inches of undisturbed original ground upon which embankments are to be constructed.
   c. Where not otherwise indicated or specified and where structures are not involved, provide Class I compaction to minimize settlement.

### 3.04 FIELD QUALITY CONTROL

**A. Density Tests:** Test compacted fill, backfill, and embankment to verify compliance with specified requirements in accordance with ASTM D2922. Conduct test frequently enough to be in accordance with the Contractor's Quality Plan, but not less than the following:

1. **Expansive Horizontal Areas:** One test per 100 cubic yards, or fraction thereof, of fill or backfill placed.

2. **Confined Areas and Embankments:** One test per every second lift of fill, backfill, or embankment placed.

**B. Compaction Tests:** Perform tests for compaction in accordance with test procedures specified in ASTM D1557, Method D, as applicable. Perform field testing of soils or compacted fill in place in accordance with applicable requirements of ASTM D2922. Perform field tests at the same frequency described for density tests.
C. Moisture Content Tests: Test the compacted fill, backfill, and embankment to verify compliance with specified requirements in accordance with ASTM D3017. Test for moisture content with the same frequency as that specified above for density test.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for designing, furnishing, installing, maintaining, operating, transferring to the follow-on contractor, and removing temporary dewatering systems and controls as required to control water levels and hydrostatic pressures during trench, station and cross passage construction. It includes constructing, maintaining, and, except where indicated or required to remain in place, removing equipment and instrumentation when no longer needed.

B. Dewatering includes intercepting seepage into the station and cross passage excavations; increasing the stability of cross passage excavations; increasing the stability of the station box excavation bottom; preventing loss of material from bottoms of excavations; pumping; disposing of pumped water; monitoring of water quality; and the proper treatment and disposal of contaminated water.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 011219, Contract Interface.
2. Section 01 41 26, Permits.
3. Section 01 45 00, Quality Assurance / Quality Control.
4. Section 01 57 24, Temporary Site Water Discharge.
5. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

1.02 SYSTEM DESCRIPTION

A. Design Requirements

1. Be responsible for the design and adequacy of the methods and systems to accomplish the following:

   a. Within plan limits of excavation, lower the groundwater level to 2 feet below bottom level of excavation throughout construction.

   b. Develop a substantially dry and stable subgrade for execution of construction operations.

   c. Prevent damage to adjacent buildings, structures, utilities, and other work that may result from settlement or other groundwater-related effects. Have dewatering design reviewed and approved by any impacted utility authorities before the start of dewatering work.
d. Comply with requirements of Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork, and instrumentation installations as shown on the Contract Drawings.

2. Methods of dewatering may include sump pumps, single or multiple stage well point systems, ejector type systems, deep wells, and combinations thereof.

3. Operate the entire system at all times through to Substantial Completion.

4. Locate dewatering systems where they will not interfere with utilities and construction work to be performed by others, including follow-on contractors.

5. Conduct groundwater discharge, conveyance, treatment, and transmission to offsite locations in a manner that meets with the approval of the City of Seattle and other governmental authorities having jurisdiction, and in accordance with Section 01 57 24, Temporary Site Water Discharge.

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Prior to installation of dewatering system, submit working drawings and design data, indicating the following:

1. The proposed type of dewatering system.

2. Arrangement, location, and depths of system components.

3. Complete description of equipment and instrumentation to be used, with installation, operation, and maintenance procedures. Submit an Operation and Maintenance Manual to the Resident Engineer within two days of system operation beginning. Include technical data on each pump, monitoring elements of the system, and a discussion of the operation, scheduled or regular checking of the operation and fueling requirements if not electric driven.

4. Types, sizes and locations of filters.

5. Design calculations demonstrating adequacy of the proposed systems and equipment.

6. Uplift calculations.

7. Methods, locations, and treatment for disposal of pumped water.

C. Qualifications of dewatering system designer and operator.

D. Copies of the special permits required for performing the work of this Section.

E. Logs of well installations.

F. Records as specified herein.

G. Quality Plan conforming to the requirements of Section 01 45 00, Quality Control, covering all dewatering operations and the field quality control to be performed.
1.04 QUALITY ASSURANCE

A. Employ a professional civil engineer or certified geologist, registered in the State of Washington and specialized in hydrogeology or geotechnical engineering, with at least 3 years experience in the design, operation and maintenance of similar dewatering systems to design and direct operation of dewatering system.

B. Provide water quality and quantity monitoring and maintain records as required by the applicable permits.

C. Groundwater discharge, conveyance and transmission are to be in accordance with Section 01 57 24, Temporary Site Water Discharge.

1.05 PROJECT CONDITIONS

A. Permits

1. Obtain all special permits and licensing for dewatering and disposal of pumped water as required to construct and complete the Work. Coordinate with requirements of Section 01 41 26, Permits.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Furnish all materials, tools, equipment, facilities, and services as required for providing the necessary dewatering work and facilities. Make available equipment, machinery and piping, including standby power and pumps in good working order and of adequate capacity to continue dewatering operations in an emergency.

B. Provide piezometers for monitoring groundwater levels and other instruments and measuring devices as required in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Dewatering System

1. Perform dewatering in accordance with working drawings and design data. Keep the Resident Engineer advised of changes made to accommodate field conditions and, on completion of the dewatering system installation, revise and resubmit working drawings as necessary to indicate the installed configuration.

2. Dispose of pumped material from excavation, and drainage from areas used or occupied for construction and other purposes. Construct pipelines, including underground portions in streets, as are necessary. Provide water to flush storm sewer and drains. If using water from the Seattle water system, obtain and pay for a fire hydrant use permit as needed. A backflow prevention device will be required and will be inspected by Seattle Public Utilities (SPU) at time of permit purchase. Arrange discharge line to facilitate taking samples by a regulatory authority.
3. Organize dewatering operations to maintain the groundwater level within excavations as required for execution of the work, and to provide a stable, dry subgrade for the execution of construction operations.

4. Operate dewatering system so that water levels outside excavation do not exceed the action limits shown on the drawings.

5. Meet quantity and quality discharge permit requirements as specified under Section 01 57 24, Temporary Site Water Discharge, for pumped water before discharging to approved points of connection to the storm or sanitary sewer.

3.02 MAINTENANCE

A. Dewatering System

1. Maintain dewatering systems in accordance with working drawings and design data.

2. Immediately replace materials, equipment, facilities that are damaged or cease to operate properly. Notify the Resident Engineer of replacements made to the dewatering system.

3.03 FIELD QUALITY CONTROL

A. Records

1. Observe and record the average flow rate and time of operation of each pump used in the dewatering system. Where necessary, provide flow meters for measuring the flow rates. Submit flow-rate data during the period that the dewatering system is in operation.

2. Observe and record the elevation of the groundwater during the period that the dewatering system is in operation. Submit observation records to the Resident Engineer within 24 hours of reading, on a regular basis.

3. During initial period of the dewatering, make required observations on a daily basis. If, after a period, dewatering operations have stabilized, reduce observations to longer intervals approved by Resident Engineer.

4. For drilled wells observe and record soil conditions, collect split spoon drive samples at 5-foot vertical intervals, prepare field log of well installations.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specification for requirements for placement of Cellular Concrete Backfill used to fill open spaces to protect waterproofing at the Low Point Sump areas.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 45 00: Quality Control.
2. Section 03 05 15: Portland Cement Concrete.
3. Section 03 30 00: Cast-in-Place Concrete.

1.02 REFERENCES

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

1. American National Standards Institute (ANSI)
   a. ANSI-B40.1 Gauge – Pressure, Indicating Dial Type – Elastic Element

   a. ASTM C33 Concrete Aggregates
   b. ASTM C94 Ready-Mixed Concrete
   c. ASTM C150 Portland Cement
   d. ASTM C311 Standard Test Methods for Sampling and Testing Fly Ash or Natural Pozzolans for Use as a Mineral Admixture in Portland Cement Concrete
   e. ASTM C494 Chemical Admixtures for Concrete
   f. ASTM C495 Standard Test Method for Compressive Strength of Lightweight Insulating Concrete
   g. ASTM C567 Standard Test Method for Determining Density of Structural Lightweight Concrete
   h. ASTM C618 Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
   i. ASTM C796 Standard Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam
1.03 DEFINITIONS

A. Backfill Concrete: Cellular Concrete Backfill which is placed to fill a void or open space.

B. Cellular Concrete Backfill: A lightweight cementitious material that contains stable air or gas cells as a preformed foam uniformly distributed throughout the mixture at a volume percentage greater than 20 percent.

C. Groundwater Seepage: Refer to Section 31 23 19, Dewatering.

D. Injection Ports: Holes cast into concrete measuring a minimum 3-inch ID which may be used to inject Cellular Concrete Backfill.

E. Inspection Ports: Holes cast into concrete measuring a minimum 3-inch ID which are used to monitor performance of Cellular Concrete Backfill.

F. Pre-production Testing: Compressive strength and density testing associated with Cellular Concrete Backfill mix design.

G. Unit Weight: The weight per unit volume of a material at a stated temperature, also referred to as density.

1.04 SYSTEM DESCRIPTION

A. Design Requirements

1. General

a. Placed in multiple lifts, if necessary.

b. Optionally use admixtures to reduce water, to control set time, and to reduce washout, segregation and bleeding.

2. Cellular Concrete Backfill

a. Cementitious Materials: Combination of Flyash and Ground Granulated Blast Furnace (GGBF) Slag shall not exceed 50 percent of total cementitious material.

b. Water Content: No more than 50 percent of total cementitious content.

c. Wet Density: Greater than 40 lb per cubic foot.

d. Strength: Minimum 150 pounds per square inch (psi) at 28 days. Minimum 150 psi at 56 days if fly ash is used.

1.05 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications.

C. Product Data:
1. General: Manufacturer's information, including brand, type, chemical analysis, and source of raw materials used in the production of Cellular Concrete Backfill.

2. Admixtures: Documentation showing that the proposed admixtures have a history of demonstrable performance.

D. Working Drawings and Methods Statements for Cellular Concrete Backfill placement.

E. Mix Design:
   1. Type and proportioning of each Cellular Concrete Backfill component.
   2. Results of trial batch cylinder compression tests or data from previous production trials with same mix design.
   3. Results of cylinder compression tests.
   4. Results of wet density tests.

F. Quality Control Plans:
   1. Procedures for verifying mix ingredient proportioning and quality, and performing sampling, testing, and record keeping.
   2. Methods for assuring that the open space is completely filled.
   3. Methods for assuring that injection pressures do not damage adjacent existing work.

G. Certifications:
   2. Calibration certificates for gauges, scales, and meters.
   3. From the manufacturer of the foaming agent material that:
      a. Flyash with carbon content at specified limit is compatible with the foaming agent, if used.
      b. GGBF Slag is compatible with the foaming agent, if used.
      c. Each admixture is compatible with the foaming agent.
      d. Mix designs in conjunction with batching, transporting, and placing means and methods are compatible with the foaming agent.
      e. The method used to introduce the foaming agent into the batching system is in accordance with their recommendations.

H. Test Reports:
   1. Pre-Production testing results: A minimum of 14 days prior to placement of Cellular Concrete Backfill.
   2. Production test reports.
      a. Include sufficient information to identify the mix used, the stationing or location of the backfill placed that corresponds to the sample tested, and the quantity placed the day the sample was taken.
b. Test data to be summarized monthly with production testing results to date for all tests and include presentation and calculation data per ASTM C495 and C567.

3. The 28-day strength test results shall be evaluated in accordance with ASTM C495.

I. Daily Placement Reports for Cellular Concrete Backfill.

1.06 QUALITY ASSURANCE

A. Qualifications:

1. Cellular Concrete Backfill Contractor: Minimum of two years performing work of similar scope.

B. Testing:

1. To demonstrate conformance with the specified requirements as indicated herein, provide the services of an Independent Testing Laboratory (ITL) per Section 01 45 00, Quality Control.

C. Acceptance Criteria:

1. Compressive Strength Tests: Evaluate and accept in accordance with ASTM C495.

2. Density: Within ± five percent of the design value.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Ensure that foaming agent containers are clearly identifiable by bearing the manufacturer’s product labeling.

1.08 WORKING DRAWINGS AND METHODS STATEMENT

A. Means and methods for proportioning, mixing, batching, and delivering Cellular Concrete Backfill, including the storage of raw materials.

B. Details for transporting concrete, injecting foaming agent, and placing material. Integrate with and describe sequencing of this work with the requirements of Section 03 30 00, Cast-In-Place Concrete. Augment with:

1. Drawings showing details of Cellular Concrete placement.

2. Descriptions of equipment and supplies required.

3. Details of pumping pressures and rates, placement volumes, including the theoretical quantity for each placement.


C. Methods for handling construction water and Groundwater Seepage and protecting Cellular Concrete Backfill.

D. Handling and disposal of all waste, including water.

1.09 INSPECTION AND TESTING

A. General:
1. Perform sampling and analysis in the presence of the Resident Engineer.

2. Test Cellular Concrete Backfill compressive strength in accordance with ASTM C495, except:
   a. Cast cylinders using Styrofoam molds; do not use plastic molds.
   b. Do not oven cure test specimens.
   c. Cap specimens with Plaster of Paris; do not use sulfur caps.

3. Test wet densities in accordance with ASTM C567.

4. Verify the suitability of optional anti-washout agents by means of a submerged demonstration.

5. Test air content in accordance with ASTM C796.

B. Trial Batch Testing:

1. To be performed if compressive strength tests are not available from previous production runs of similar materials and design parameters.

2. A minimum of one mix design.

3. A minimum of three cylinders for seven day, 14 day, and 28 day tests and six cylinders for 56 day tests.

4. Compressive strength test results shall be supplied for seven day, 14 day, 28 day, and 56 day tests.

5. Equal number of cylinders for every variable changed in the mix.

C. Pre-Production Testing:

1. Perform wet density test on the proposed Cellular Concrete Backfill mix.

2. Take three sets of three cylinders.

3. Perform compressive strength tests on each set of samples at seven days, 14 days, 28 days, and 56 days (if needed).

4. Source of materials shall not be changed during the course of the work unless compressive strength testing is reconfirmed.

D. Cellular Concrete Production Testing:

1. Compressive Strength tests:
   a. Verify strength test of Cellular Concrete Backfill placed, with testing by the ITL.
   b. Verification shall be accomplished by testing standard cylinders of Backfill Concrete Backfill samples taken at the Site in accordance with ASTM C495.
   c. For the first 24 hours after casting, the cylinders shall be kept moist in a storage box constructed and located near the point of placement so that its interior air temperature shall be between 60 degrees F and 80 degrees F.
d. At the end of 24 hours, the cylinders shall be transported to the ITL.

e. Final strength test result shall be the average of the strengths of two test cylinders at 28 days, except that if one cylinder in a set of two shows evidence of low strength due to improper sampling, casting, handling or curing, the result of the reserve cylinders shall be used.

f. The average of any three consecutive 28-day strength test results from cylinders representing each Cellular Concrete Backfill mix shall be equal to or greater than the specified strength. Less than ten percent of the strength test results shall have values less than the specified 28-day strength for the total backfill operation. No individual strength test results shall be less than the specified strength by more than 40 pounds per square inch.

g. If the 56-day test results fall below the specified compressive strength for the class of Cellular Concrete required, adjustment shall be made in the proportions, water content, or both, as necessary. Report changes and adjustments in writing to the Resident Engineer.

2. Wet Density: As specified herein.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Foaming Agent:

1. Conform to ASTM C869 when tested in accordance with ASTM C796.

2. Capable of generating foam, which maintains stability until the cement sets to form a self-supporting matrix comprising closed cells and low water absorptive characteristics.

3. Approved manufacturers:
   a. Mearl Geofoam Liquid Concentrate, Mearl Corporation.
   b. Rheocell 30, Master Builders Inc.
   c. WF 304 Foam Concentrate, Cellufoam Concrete Systems.
   d. MaxFlow Foaming Agent Concentrate, MaxFlow Environmental Corp.
   e. Elastizell, Elastizell Corporation of America.
   f. Approved equal.

B. Admixtures:

1. General: Do not use admixtures containing chlorides, that promote corrosion or that have not been specifically approved for use with foaming agent by foaming agent manufacturer.

2. Retarder/Water Reducer: Conforming to ASTM C494, Type D.
3. Plasticizer/Water Reducer: Conforming to ASTM C494, Type A.
4. Water Reducer, High Range: Conforming to ASTM C494, Type F.

C. Cement: Conforming to ASTM C150, Type II.

D. Fly Ash: Conforming to ASTM C618, Class F, compatible with the submitted Foaming Agent.

E. GGBF Slag: Conforming to ASTM C989, Grade 100 or Grade 120, compatible with the submitted Foaming Agent.

F. Water: Clean and potable conforming to ASTM C94.

2.02 EQUIPMENT

A. General:
1. Sufficient size to batch and pump the required volume of Cellular Concrete Backfill over the distance required at a uniform flow rate and under the required constant pressure in an underground environment.
2. Configure equipment to flush system with intake valves closed, with water supply valve open, and with pump running at full speed.
3. Capable of generating Cellular Concrete Backfill with a density within ± five percent of the design density.
4. Maintain equipment in good operating condition and provide an adequate inventory of spare parts and backup equipment on Site to assure that the equipment is available at all times.

B. Batching:
1. Provide graphic or digital printout record of batch scale readings, accurate to 1.0 lb. of dry mix ingredients before delivery to mixer.
2. Cellular Concrete Foam Generator:
   a. Capable of generating foam by combining controlled quantities of air, water, and foaming agent under pressure in accordance with the foaming agent manufacturer’s recommendations.
   b. Capable of providing timer controls to repetitively discharge a pre-selected quantity or to continuously discharge at a fixed rate.

C. Mixing:
1. Configure mixer to be compatible with the pump to assure continuous and uniform flow at the point of placement.
2. Provide a mixer capable of providing a super-wetted, homogenized mix.
3. Equip mixer with a water meter with an accuracy of ± one gallon for measuring the amount of mixing water to be added to the dry mix ingredients.

D. Pumping:
1. Provide equipment capable of pumping the amounts of Cellular Concrete Backfill to be conveyed without pulsation or segregation.
2. Capable of uniformly conveying a continuous stream of Cellular Concrete Backfill, without air pockets.

3. Equipped with pressure limit device to limit pumping pressure as required to prevent damage to surrounding structures.

E. Piping, Injection Hoses, Valves, and Connections:
   1. As required to convey Cellular Concrete to the point of placement in steel piping or rubber hoses.
   2. Provide piping, injection hoses, valves, and connections of no less than two inches ID.
   3. Provide a system of valves in the line at or near the points of injection to facilitate collecting samples.
   4. Incorporate suitable stop valves at injection points for use in venting air or maintaining pressure, as required.

F. Pressure Gauges:
   1. Displaying up to 150 percent of the maximum allowable pressure and accurate to within ± 0.5 percent over the full range of the gauge.
   2. Certified and calibrated in accordance with ANSI B40.1, Grade 2A.
   3. Oil-filled type gauges attached to a saddle-type diaphragm seal.

PART 3 - EXECUTION

3.01 PREPARATION

A. Verify that locations where Cellular Concrete Backfill is to be placed are clean and clear of all loose and deleterious materials.

B. Verify that Groundwater Seepage inflows will not impact placement.

C. Provide Groundwater Seepage controls to prevent water from infiltrating into Cellular Concrete Backfill.

D. Install valves at each Inspection Port which are open at the locations where Cellular Concrete Backfill is to be placed.

E. Complete Cellular Concrete Backfill pre-production material testing and confirm that materials proposed meet requirements specified.

F. Do not start production backfill operations until pre-production testing is completed and results meet specified requirements.

3.02 INSTALLATION

A. Provide a means of direct communications between the Injection Point and the pump operator.

B. Limit lift heights as required to ensure stable air cells in Cellular Backfill Concrete mix is maintained above 20 percent limits as defined.

C. Batching:
1. Mix sufficiently to prevent flocculation.
2. Prevent excessive mixing after introducing the foam to prevent changes in Cellular Concrete Backfill unit weight and consistency.

D. Completely fill open spaces using the injection ports:
1. In lifts, as needed.
2. Open Inspection Ports to vent Cellular Concrete placement and monitor progress of work.
3. Close valves at Inspection Ports and Injection Ports when Cellular Concrete Backfill returns through them.

3.03 FIELD QUALITY CONTROL

A. General:
1. Provide delivery and measurement of materials from batching equipment to within the accuracies specified in ASTM C94.
2. Sample and test fine aggregate, when used, in accordance with Section 03 05 15, Portland Cement Concrete.
3. Sample and test fly ash in accordance with ASTM C311.
4. Test and calibrate equipment to generate foam each day for density and volume output. Maintain calibration records and make available to the Resident Engineer on request.
5. Provide batch tickets at a minimum for every 10-cubic yards of Cellular Concrete Backfill in accordance with ASTM C94 with other optional information:
   a. Identify the wet density.
   b. Identify mix design.
   c. Identify approximate location of injection.
   d. Identify total mixing water.
   e. Identify reading from revolution counter at first addition of water.

B. Collect samples for testing at the Injection Point.

C. Measure, record, and compare volume of concrete placed with the theoretical volume. Monitor the advance of the Cellular Concrete Backfill through Inspection Ports during the concreting operation.

D. Testing and Sampling:
1. Wet Density:
   a. Sample and test in accordance with mix design utilized.
   b. Prior to introduction of the foaming agent and noting the time.
   c. After a change in the mix batched.
d. Whenever compressive strength test cylinders are made.

2. Compressive Strength Tests:
   a. Two sets of three cylinders for every 150 cubic yards placed, but no less
      than two sets per day.
   b. Test one cylinder at seven days, two cylinders at 28 days, and two at 56
      days (if needed). The remaining cylinder from each set shall be used as
      needed to substantiate test results not meeting design parameters.

3. Tests for air content: Measured and recorded in accordance with ASTM C796.

E. Daily Placement Report:
   1. Date, location, and time of injection at each injection point used.
   2. List of personnel, equipment, and reason for any down or idle time.
   3. Listing of all materials used.
   4. Batch Tickets.
   5. Results of Wet Density testing.
   6. Record of Test samples taken, including locations.
   7. Record of actual and theoretical volume of placement, and all testing performed.
   8. Location of Inspection Ports where Cellular Concrete Backfill was observed to
      flow through.

3.04 CLEAN-UP
   A. Remove waste materials and other debris from the tunnels.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for excavating, trenching, and backfilling for utilities and related structures, as indicated, including underground piping for water supply, sanitary sewerage, storm sewerage, underground electrical conduits and duct banks, and utility boxes, catch basins, manholes, and vaults.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 71 23, Field Engineering
2. Section 31 20 00, Earth Moving
3. Section 31 23 19, Dewatering
4. Section 31 50 00, Excavation Support and Protection
5. Section 33 01 00, Operation and Maintenance of Utilities

1.02 REFERENCES

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

1. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge, and Municipal Construction
   b. Standard Plans for Municipal Construction

2. Seattle City Light Material Standards

3. Seattle Department of Transportation:
   a. SDOT Director's Rule 2004-02, Street and Sidewalk Pavement Opening and Restoration.

   a. WAC 296-155 Part N: Safety Standards for Construction Work, Excavation, Trenching and Shoring

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Material source, and all tests and certifications necessary to approve material, including moisture/density relation test results. If on-site material is proposed for use as any of the materials specified in construction, provide test results certifying suitability of said material.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Bedding and Backfilling Materials:
   1. Water line bedding: Class B bedding in accordance with COS Standard Plan 350. Mineral Aggregate Type 9 in accordance with COS Specification Section 9-03.
   3. PVC Sanitary Sewer pipe bedding: Class B bedding in accordance with COS Standard Plan 285. Mineral Aggregate Type 22 in accordance with COS Specification Section 9-03.
   4. Storm Drainage rigid piping bedding: Class B bedding in accordance with COS Standard Plan 285. Mineral Aggregate Type 9 in accordance with COS Specification Section 9-03.
   5. Bedding for underground electrical conduits and duct banks shall conform to the Seattle City Light Material Standards 7150.0.
   6. Trench Backfill: Imported Mineral Aggregate Type 17 conforming to COS Specification 9-03.16 or a similar material approved by the Resident Engineer.

PART 3 - EXECUTION

3.01 CONSTRUCTION
A. Prior to digging see Section 33 01 00, Operation and Maintenance of Utilities, for additional requirements.
B. Staking and Grades:
   1. Refer to Section 01 71 23, Field Engineering, for requirements.
C. Existing Utilities:
   1. Refer to Section 31 20 00, Earth Moving, Article 3.01B, for requirements.
D. Protection of Persons and Property:
   1. Erect and maintain temporary bracing, shoring, lights, barricades, signs, and other measures as necessary to protect the public, workers, and adjoining improvements from damage during trenching work in accordance with applicable codes and regulations.
   2. Protect utilities, pavements, and facilities from damage caused by settlement, lateral movement, undermining, washout, and other hazards created by the trenching operations.
3. Protect open trenches outside of secured fence areas with steel plates with non-slip surfaces or water filled barriers during non-working hours. Provide barriers to block pedestrians or vehicles from entering the work area and approaching trenches during working hours.

E. Dewatering

1. Prevent surface water and subsurface or ground water from flowing into excavations and from flooding project site and surrounding area.

2. Where water is encountered in the trench, dewater as specified in Section 31 23 19, Dewatering.

3. Provide and maintain pumps, sumps, suction and discharge lines, and other dewatering system components necessary to convey water away from excavations.

4. Establish and maintain temporary drainage ditches and other diversions outside excavation to convey water. Do not use trench excavations as temporary drainage ditches.

F. Trenching and Excavating:

1. Perform work in accordance with the requirements of WAC 296-155, Part N, Excavation, Trenching and Shoring.

2. Do not undermine or disturb sidewalks, pavements, appurtenant structures, adjacent improvements or underground installations adjacent to and beyond the trench.

3. Excavate to the depth, line, and grade indicated on the Contract Drawings.

4. Excavate using open cut methods.

5. Keep the length of trench excavation in advance of pipe installation operations to a minimum and do not exceed 200 feet.

6. The maximum trench width in the Right of Way shall not exceed the neat line trench width as shown or indicated in the Contract Drawings.

7. Outside the Right of Way and in unimproved areas, trench width above the top of pipe may at the Contractor’s option exceed the neat line trench width indicated on the Contract Drawings by sloping or benching. All requirements for excavating, handling and disposing of excavated material, and placing and compacting additional suitable backfill, outside of the neat line trench limits shall be at the sole expense of the Contractor.

8. Excavate to the inverts indicated on the drawings plus any additional excavation as necessary to accommodate the Contract specified class of bedding. Provide over-excavation for the pipe bells such that pipe barrels and bells along the pipe are uniformly supported full length.

9. Grade surrounding areas or utilize alternative controls to prevent surface water from flowing in to the excavations.

10. Maintain at least 3 feet of separation from the toe of the slope of any stockpiled excavated material from the trench edge.
11. For utility structures, provide a minimum of 12 inches between the exterior surfaces of utility structures and the sides of the excavation.

12. All ledgerock, boulders, stones, and any object larger than 3 inch in any dimension shall be removed within 6 inches in any direction from the pipe.

13. Remove trench protective systems in such a manner as to not disturb bedding or backfill. Where bedding or backfill is disturbed, reconsolidate the material as specified.

14. Ensure excavations for structures conform to the applicable requirements of Section 31 20 00, Earth Moving.

G. Bedding:

1. For Water Mains:
   a. Place bedding in accordance with the dimensions indicated on the Contract Drawings or as referenced in a COS Standard Plan.
   b. Provide uniform support along the entire pipe barrel, without load concentration at joint collars or bells. Provide over-excavation for the pipe bells such that pipe barrels and bells along the pipe are uniformly supported full length.
   c. Do not use blocking to adjust pipe to grade.
   d. Reconsolidate bedding disturbed by pipe movement or by removal of trench protection prior to backfill.
   e. Take special care to provide adequate bedding support at wye or tee connections and adjacent manholes or other structures to avoid bending or shearing stresses at these critical points.

2. Pipe Bedding for Storm Drains and Sanitary Sewers as specified in the City of Seattle Specifications Section 7-17.3(1)B and in accordance with COS Standard Plan 284 and 285.

3. Bed duct banks on 2 inches of compacted washed sand as indicated.


H. Backfilling: Backfill with material indicated. Take all necessary precautions to protect the pipe, duct bank or vault from any damage or shifting.

1. Pipe and duct bank Backfilling: Backfill from the side of the trench to a uniform depth of 1 foot above ductile iron pipe before starting compaction, and to a uniform depth of 2 feet above concrete pipe and duct banks before starting compaction.

2. Electrical Vault backfill in accordance with Seattle City Light Construction Guideline U2-15.1.

I. Compaction: Refer to Section 31 20 00, Earth Moving. The requirement for compaction is Class II Compaction in improved areas such as parking lots or sidewalks. The compaction requirement in unimproved areas or landscaped areas is Class I Compaction.
J. Restoration:

1. Comply with surface restoration requirements as indicated in the Contract Drawings, Contract Specifications, or as referenced in a COS Standard Plan.

2. In City of Seattle Right-Of-Way, comply with City of Seattle’s Director’s Rule for Street and Sidewalk Pavement Opening and Restoration.

3.02 FIELD QUALITY CONTROL:

A. Refer to Section 31 20 00, Earth Moving, for requirements.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for ground treatment utilizing Jet Grouting methods. The location and extent of the required jet grouting are shown on the Contract Drawings.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
2. Section 01 57 19, Temporary Environmental Controls.
3. Section 01 74 00 Cleaning and Waste Management
4. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

1.02 REFERENCES

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

1. American Society for Testing and Materials (ASTM)
   a. ASTM C94 Standard Specification for Ready-Mixed Concrete
   b. ASTM C150 Standard Specification for Portland Cement
   c. ASTM C494 Standard Specification for Chemical Admixtures for Concrete
   d. ASTM C618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
   e. ASTM C989 Standard Specification for Ground Granulated Blast-Furnace Slag for Use in Concrete and Mortars
   f. ASTM D1633 Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders
   g. ASTM D4044 Standard Test Method (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
   h. ASTM D4050 Standard Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems

2. American Petroleum Institute (API)
   a. API 13A Specification for Drilling-Fluid Materials
3. Codes and regulations of the City of Seattle.

1.03 DEFINITIONS

A. Jet Grouting: The process of injecting cement grout to create an in-situ soil-cement column to allow excavation with minimal water ingress and to provide a stable crown and face for excavation. The cement grout is injected and mixed with the soil under high pressure through nozzles at the end of a monitor inserted in a borehole. The monitor is rotated and lifted at slow, smooth, constant speed to achieve a continuous geometry and quality of soil-cement.

B. Column Spacing: The theoretical designed offset between the axes of adjacent jet grout columns in any direction required to provide the design Column Overlap.

C. Column Overlap: The distance by which one column periphery is designed to overlap an adjacent column periphery such that a homogeneous block of treated ground is created.

D. Drilling deviation: The deviation of the drill hole from a theoretical straight line.

E. Spoil Returns: Excess jet grouting materials, including grout and soil that return through the drill hole and drill collar to the ground surface.

F. Single System: A jet grouting system where a high pressure jet of cementitious grout is used to disaggregate the ground.

G. Double System: A jet grouting system where a high pressure jet of cementitious grout surrounded by an annulus of air is used to disaggregate the ground.

H. Triple System: A jet grouting system where a high pressure jet of water surrounded by an annulus of air is used to disaggregate the ground with separate injection of cementitious grout.

I. Closure Column: An additional column installed to maintain column overlap in the event of excessive drilling deviation.

J. Contingency Procedure: The procedure to implement additional measures as required by ground conditions.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications:
   2. Jet Grouting Engineer.
   4. Independent Testing Laboratory.

C. Results of calibrations.

D. Shop Drawings: Design, specifications, method of operation, supporting calculations, and other data pertaining to but not limited to the following:
2. Production control.
3. Quality Control by laboratory testing.
5. Permeability test methods

E. Jet Grouting Work Plan.

F. Documentation:

1. Daily: Signed by the Jet Grouting Engineer and submitted within two working days. Record and show:
   a. Day, month, year, time of the beginning and end of the work shift; all workers’ names associated with each jet grouting rig; and a summary of equipment used during the shift.
   b. Time of beginning and completion of each soil-cement installed during the work shift. Location and reference number of each completed column.
   c. Water-cement ratios, cement type, brand and compound composition; cement grout injection pressures and rates, other pertinent cement grout mix data, mixing rotational speeds, penetration and withdrawal rates of the jet grouting equipment, and installation sequence for every soil-cement element including detail of jet nozzles.
   d. Other pertinent observations including, but not limited to: spoil returns, cement grout escapes, ground settlement or heave, collapses of the soil-cement element, advancement rates of the jet grouting equipment, and any unusual behavior of any equipment during the jet grouting process and other noteworthy events.
   e. Date, time, plan location, sample designation and elevation, and other details of soil-cement sampling and other quality control and field testing.
   f. Summary of any unproductive time, including start and end time, duration, and reason.
   g. Produce a graphical record of the jet grouting operation. Include the following:
      1) Graph of rotation speed, rate of withdrawal, grout pressure, grout flow, air pressure and air flow plotted against depth.
      2) Graph of drill hole deviation in two orthogonal directions.
      3) Plan showing as-built and design position of the jet grout columns at the top and bottom of the jet grout block.
      4) Plan showing any proposed setting out of required closure columns.
   h. Have the daily records checked for correctness and signed by the jet grouting Superintendent.

2. Weekly: Calculated elevations of ground level, top and base of all jet grout columns.
3. Results of all quality control tests completed during the previous week.

G. As-Built Plan of Ground Treatment: Prepare the as-built plan to a scale acceptable to Resident Engineer. Show all treatment points (and their reference numbers) and locations and types of tests carried out.

H. Survey Control:
   1. Type and location of horizontal and vertical control monuments to be set.
   2. Survey procedures, including equipment and software.

1.05 QUALITY ASSURANCE

A. Qualifications:
   1. Jet Grouting Subcontractor: Demonstrate the following relevant experience: Three projects completed successfully within the last seven years, each demonstrating the following characteristics:
      a. Jet grout columns installed to 100 feet below surface, achieving adequate interlock and average minimum soil mass compressive strengths of over 200 psi.
      b. Inclined jet grouting at angles of up to 20 degrees from vertical at depths of over 100 feet.
   2. Jet Grouting Engineer:
      a. A graduate engineer from an ABET-accredited college, university or foreign equivalent.
      b. A minimum of 5 years combined field and design experience in jet grouting as specified herein.
   3. Jet Grouting Superintendent:
      a. A minimum of 5 years experience installing jet grouting of similar scope and complexity.
      b. Present on site full time during jet grouting.
   4. Independent Testing Laboratory: Minimum of 3 years experience with testing specified herein, and in accordance with Section 01 45 00, Quality Control.

B. Survey Control: Provide qualified survey personnel in accordance with Section 01 71 23, Field Engineering.

C. Calibration: Performed on a quarterly basis by an approved testing agency, for all gages, scales and meters used to perform the work.

1.06 JET GROUTING WORK PLAN

A. Detailed descriptions, data and calculations of proposed materials, facilities, and equipment to be used, including but not limited to the following:
   1. Equipment:
      a. Drilling equipment.
b. Drill alignment measuring equipment.
c. Drilling deviation control and monitoring equipment.
d. Drilling depth control and monitoring equipment.
e. Batching and mixing plant for grout production.
f. Grout quality assurance equipment.
g. High-pressure grout pumps.
h. High-pressure air compressors.
i. Jetting nozzle diameter measurement equipment.
j. Jet grouting column production monitoring equipment.
k. Other equipment.

2. Materials:
a. Grout Mix Designs.
b. Portland Cement.
c. Ground Granulated Blast Furnace Slag.
d. Fly Ash.
e. Bentonite.
f. Cement additives.

B. The following information for methods of construction:

1. Description of system proposed, whether Single, Double or Triple system, as well as anticipated nozzle pressure, rotation speed, and extraction rate, appropriate for anticipated subsurface conditions.

2. Details of any trials proposed to confirm column diameter, drilling tolerances and column strength.

3. Key installation plan showing column placement including proposed column spacing and design overlap, depths of placement, angles of inclination, drill hole deviation allowance and provision for closure columns.

4. Proposed jet grout column diameter and methods for determining diameter in situ.

5. Sequence of jet grouting including jetting parameters and contingency methods where drill holes exceed design drill hole deviation.


7. Drilling method including setup alignment measurement and control, drilling deviation measurement and control, and directional accuracy.
8. Complete environmental control plan detailing methods for controlling, containing and disposing of all byproducts of the jet grouting operation, in accordance with Section 01 57 19, Temporary Environmental Controls.

9. Quality assurance procedures for grout production.

10. Monitoring and recording of jet grouting parameters.

11. Coordinate requirements for monitoring settlements and heave with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.


C. The following information for the performance requirements:

1. Drilling method to retrieve core samples.

2. Location of planned coring.

3. Operational plan to determine in-situ permeability and strength within specified requirements.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Have adequate supply of required materials for jet grouting present at site at all times.

B. Deliver, store, and handle materials to prevent contamination, segregation, corrosion, or damage.

C. Store cement materials in a dry place and in accordance with Suppliers’ specification. Maintain materials in a clean and undamaged condition. Be responsible for replacing damaged or destroyed materials at no cost to Sound Transit.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Cement Grout

1. Portland Cement: ASTM C150, Type II.

2. Provide bulk cement with methods of measurement, handling, transporting and storing that conform to the manufacturer’s recommendations. Should cement be furnished in cloth or paper bags, package within plastic or rubber vapor barriers.

3. Grout Mix Properties: Proportioned to provide the required strength when mixed with soil as specified herein, and of mixing consistency as required to perform the work.

B. Water

1. Clean and potable.

2. Meets requirements of ASTM C94.

C. Alternative Cementitious Materials

1. Fly ash:
a. ASTM C618, Class F, with weight loss on ignition limited to three percent.

b. Limit fly ash to a maximum of 20 percent by weight of total cementitious materials.


D. Admixtures


2. Do not use admixtures that have exceeded the manufacturer’s recommended shelf life.

3. Deliver, store and handle admixtures in accordance with the manufacturer’s recommendations.

E. Bentonite: API Recommended Practice 13A. Protect bentonite from moisture and contamination both in transit and during storage at the site.

2.02 EQUIPMENT

A. Drilling Equipment: Proven performance for use in performing jet grouting work.

B. Mixers, Holding Tanks and Associated Equipment: Type and capacity for producing uniform grout mixtures at all times and in the quantities required for the timely execution of the work.

C. Jet Pumps: High pressure pumps capable of delivering the grout at the flow rates and pressure required.

D. Recording Equipment:

1. Automatic recording equipment with a meter to determine the volume of grout injected.

2. Calibrated in gallons to the nearest quarter-gallon (1/4 gallon).

E. Grout Plant: Consisting of a mixer, agitated sump, grout pumps, gages, valves, pressure lines, and all other equipment necessary to mix and perform grouting as required.

2.03 MIXES

A. Strength

1. 28-day Unconfined Compressive Strength shall be at least 300 psi for jet grout columns, tested in accordance with ASTM D1633.

2. Obtain 4-inch minimum diameter cylinders for determination of strength for mix design testing, or as specified herein for wet grab sampling cylinders.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Environmental and Safety Requirements
1. Maintain site in a clean and orderly state to the satisfaction of the Resident Engineer. Provide, install and maintain environmental controls to contain and dispose of surface runoff water, grout and drilling fluid overflows including, but not limited to:
   a. Containment walls and dikes with membrane barriers
   b. Sumps and cleanouts
   c. Silt traps
   d. Liquid storage tanks

2. Perform work in a manner that minimizes safety hazards and exposure of personnel and equipment to hazardous and potentially hazardous conditions in accordance with specified safety requirements.

3. Assess all ground and groundwater conditions, and working platform construction at all times during the construction period and react prudently and swiftly to all indicators and conditions.

4. Provide safe work areas and temporary platforms and stands at all times.

5. In case of emergency or work stoppage likely to endanger excavation or adjacent structures, continuously maintain full work force 24 hours per day including weekends and holidays until emergency or hazardous conditions no longer jeopardize stability and safety of the structures.

6. Dispose of Spoil Returns in accordance with Section 01 74 00, Cleaning and Waste Management.

B. Surveying and Setting Out

1. All drill holes to be set out to within 0.25 foot of the design position and elevation.

2. Initial drill inclination and azimuth to be set up to within 0.5 degree of design values.

C. Drilling for Jet Grouting

1. Provide suitable drilling equipment capable of drilling to the depths and inclinations required.

2. Fit each drill rig with instrumentation to monitor drilling inclination and bearing to the required tolerances.

3. Check drill rig at set up and at a depth increment of 25 feet for positional accuracy, bearing and drilling inclination. Note any deviations outside of the specification and redrill the hole in accordance with the operation procedure plan.

4. Following review of the drill hole deviation measurements, adjust column size and grouting procedures as necessary to provide required ground treatment coverage.

D. Jet grouting

1. Use equipment that can be controlled to the desired design rate of withdrawal, rotation, grout flow and pressure, airflow and pressure. As a minimum maintain all designated parameters within a tolerance of five percent.
2. Use equipment that records the parameters set out herein with real time display to allow the jet grout operator to control the column construction to the required tolerances.

3. Maintain equipment in fully functional state; in particular provide an operational procedure for checking jet grout nozzle(s) for efficiency and diameter.

4. Where the jetting of a column is interrupted for any reason including the addition or removal of drill rods, then reintroduce the jet grout stem into the column by a minimum distance of 12 inches.

5. Commence jetting from the bottom and withdraw towards the upper limit of ground treatment.

6. Coordinate jet grouting operations with other aspects of the work. Install jet grouting in a manner so as to not create obstructions or other hindrances to subsequent aspects of the work.

7. Perform construction in a manner that limits subsidence or heave of surface in vicinity of the works to 1/2 inch. Movements will be monitored in accordance with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

8. React diligently to drill hole blockages to prevent ground movements.

9. Complete jet grouting for the entire area as shown on the Contract Drawings.

3.02 FIELD QUALITY CONTROL

A. Quality Assurance of Grout

1. Produce grout such that jet grouting will not be interrupted due to insufficient grout being available.


3. Provide a series of agitating tanks to allow acceptance or rejection of grout to be carried out. Screen material from the mixers prior to entering the agitating tanks.
   a. Capacity of the holding tanks shall be adequate to sustain continuous operations.
   b. Fit the tanks with a graduated dip-stick capable of recording the volume of grout in the tank.

4. Perform the following testing once per shift or operation and record separately:
   a. Unconfined Compressive Strength of set grout and soil mixture at 28 days.

B. Quality Assurance Of Jet Grouting

1. Maintain all column setting out data, positional data, grouting parameters, and performance testing on a computer database for ease of assessment of jet grouting overall performance. Coordinate software and format for the database to be consistent with other requirements for record keeping specified herein.

C. Performance requirements:

1. Wet Grab Sampling
a. Perform a minimum of one in situ sampling round, defined as a test suite, at a frequency of once per every 100 installed jet grout columns, at locations selected by the Resident Engineer. Obtain the entire suite of jet grout samples at the same element, consisting of a non-cured jet grout sample obtained at three depths selected by the Resident Engineer.

b. Retrieve separate jet grout samples within 30 minutes of the withdrawal of the mixing equipment at a specific location. Use a device to retrieve the wet grab jet grout samples that is capable of obtaining a discrete fluid sample of jet grout at a pre-determined depth and is capable of accepting particles not thoroughly mixed that are up to 4 inches in dimension. Lower the sampler empty, air only, to the required depth in the jet grout column and then open. Close the sampler once filled with the jet grout to exclude entry or loss of jet grout and expeditiously raise to the ground surface.

c. Retrieve jet grout samples of sufficient volume to produce a minimum of four full cylinders, 2-inch diameter by 4-inch height. Form cylinders of material passing through a 3/4-inch sieve.

d. Store samples and test all jet grout cylinders by the Independent Testing Laboratory for unconfined compressive strength in accordance with ASTM D1633.

2. Coring

a. Perform vertical coring from ground level.

b. Obtain five cores for ground treatment zone, spaced across the ground improvement zone, excluding the field test program, at locations approved by the Resident Engineer.

c. Take each core over a vertical distance within 5 feet of the base of the ground treatment zone. Log each core hole for quality of grouting and other observations.

d. Take 8-inch long samples and seal for UCS determination. Take a minimum of three samples from each core hole.

e. Fully backfill hole with cement grout after completion of all sampling and ground water inflow measurements.

3. Field Test Program:

a. Conduct test programs to evaluate the proposed grouting methods and the ability of the proposed grout mix to produce grout columns meeting the diameter, overlap and material property requirements.

b. Perform one test program at a location approved by the Resident Engineer.

c. Locate each test program in a portion of the ground treatment zones that can be incorporated into the finished work. Locate to avoid impacts on adjacent roadways, utilities, and other surface features to the extent possible.

d. Install six jet grout columns for each test program, consisting of two rows of three columns each, for the full depth of ground treatment.
e. Collect and submit daily records in the same fashion as production jet grouting.

f. Core inspection for each test program:
   1) After the jet grout columns have set up sufficiently, obtain continuous core samples from the center of two of the columns. Also obtain continuous cores from the overlapping edges at two locations, as selected by the Resident Engineer.
   2) Inspect and log the cores and check for segregation.
   3) Confirm design column overlap.
   4) Select three samples from each of the two cores taken at the center of the columns and test in accordance with ASTM D1633 for 28-day strength.
   5) Complete core inspection prior to installation of additional jet grout columns.

g. Depending on the results of the test program, modify the jet grout parameters to meet design criteria if necessary.

h. Where the test program and results fail to achieve the design criteria, modify the jet grouting approach and install additional test columns, per direction of the Resident Engineer.

4. Non-Compliance
   a. Criteria for Wet Grab Sampling:
      1) Unconfined Compressive Strength: As specified herein.
   b. Criteria for Vertical Coring and Field Test Program Coring:
      1) Ungrouted sections of column exceed 10 inches in length.
      2) More than five percent of the cored length is ungrouted.
      3) Unconfined Compressive Strength: As specified herein.
   c. Where test results indicate non-conformance with the specification, propose remedial works to rectify the situation to the approval of the Resident Engineer. Submit this proposal in a timely manner so as to prevent delay to the operations.

5. Permeability
   a. Observe and record inflows for each core hole once per day for a minimum of three days prior to backfilling hole. Perform permeability testing in the presence of the Resident Engineer.
   b. Limit permeability of core hole: 3.8x10^-8 feet per second, per hole, averaged over the three-day period.
   c. Where test results indicate non-conformance with the specification, propose remedial works to rectify the situation without delay to the approval of the Resident Engineer.
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specification for minimum requirements for design and implementation of Ground Treatment using Permeation Grouting.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19, Contract Interface.
2. Section 01 57 13, Temporary Erosion and Sediment Control.
3. Section 01 57 24, Temporary Site Water Discharge.
4. Section 01 74 00, Cleaning and Waste Management.
5. Section 01 78 39, Project Record Documents.

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

1. American Petroleum Institute (API)
   a. API 13A Drilling Fluid Materials

   a. ASTM D422 Gradation Testing of Soils
   b. ASTM C150 Portland Cement
   c. ASTM C494 Chemical Admixtures for Concrete
   d. ASTM C136 Sieve Analysis of Fine and Coarse Aggregates
   e. ASTM D1633 Standard Test Method for Compressive Strength of Molded Soil-Cement Cylinders
   f. ASTM D2834 Standard Test Method for Permeability of Granular Soils (Constant Head)
   h. ASTM D4832 Standard Test Method for Preparation and Testing of Soil-Cement Slurry Test Cylinders

B. Qualifications:

1. Grouting contractor: No less than three projects completed within the last five years, each including the planning and execution of a Ground Treatment program with permeation grouting that was similar in scope and type to that planned for this Contract.

2. Ground Treatment Manager: Full-time, on-site individual in responsible charge for all Ground Treatment operations, with a minimum of five years of experience in the design and field application of the methods utilized to perform the work planned for this Contract.

3. Grout Design Engineer: A minimum of five years experience in the design and application of grouting systems and is currently licensed as a Professional Engineer registered in the State of Washington.

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Design Data for Permeation Grouting.
C. Design and Plans: Volumes for ground treatment, design assumptions, and calculations.
D. Quality Control Plans.
E. Mix Designs.
F. Daily Shift Reports: Within eight hours of the end of the shift.
G. Record document drawings indicating area and components of ground treatment.
H. Erosion and Sediment Control Plan, coordinated with requirements of Section 01 57 13, Temporary Erosion and Sediment Control.

1.04 DEFINITIONS

A. Ground Treatment: A general term referring to the use of Permeation Grouting to permanently modify the existing in-situ soil and groundwater conditions to enable stable excavation of adjacent soil and provide groundwater control.
B. Grouting: General term referring to the injection of cement, water, bentonite, sodium silicate, or other materials designed to perform Ground Treatment.
C. Permeation Grouting: Process of injecting a solution or particulates into the soil to fill void spaces.

1.05 DESIGN CRITERIA

A. Permeation Grouting shall be used for Ground Treatment at locations as indicated on the Contract Drawings.
B. Design to improve the soil conditions present to meet the criteria indicated herein.
C. Permeation Grouting:

1. Cement grout composed of water, bentonite, cement, fluidifier, and/or possibly sand.
   a. Grout mix shall be such that, when injected into medium dense No. 17 Bank Run Gravel, per City of Seattle Standard Specifications Section 9-03, the confined compressive strength of the grouted soil shall average at least 200 psi.
   b. Alternate grout materials may be submitted for possible substitution in accordance with Section 01 25 00, Substitution Procedures.

1.06 QUALITY CONTROL PLANS

A. Methods and plans for demonstrating that Ground Treatment meets design criteria.

B. Inspection, testing, monitoring, and sampling methods, where not otherwise indicated, for determining compliance with design criteria.

C. Methods for controlling and verifying the vertical limits of the Ground Treatment.

D. Criteria, equipment, and procedures for abandoning or remedying grouting occasioned by equipment failure, inadequacy of grout mix or delivery systems, or other cause.

1.07 DESIGN AND PLANS

A. Design calculations stating all design assumptions for the Permeation Grouting based on anticipated subsurface conditions.

B. Shop Drawings:
   1. The arrangement, spacing, and diameter of boreholes relative to the methods and mixes used. Include extent and depth of the grouted mass.
   2. Stamped, dated, and signed by the Grout Design Engineer.
   3. Profile views of Ground Treatment zones, showing relationship with adjacent shaft.

C. Equipment, methods, and details of Grouting operation. Include:
   1. Arrangement of grout mixing and injection equipment.
   2. Clearances from adjacent facilities.
   3. Sequence and details of drill-hole placement.
   4. Minimum set time and strengths.

D. Details for identifying, protecting, and maintaining utilities in working service.

E. Means and methods for handling, treating, and disposing of excess and spilled materials generated during the Grouting operation including changes to the erosion and sediment control system.

1.08 MIX DESIGNS
A. Submit proportions of materials proposed for each grout mix design.

1.09 EROSION AND SEDIMENT CONTROL PLAN
A. See Section 01 57 13, Temporary Erosion and Sediment Control.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Cement Grout:
   1. Portland cement, ASTM C150, Type I, II, or III.
   2. Fluidifier: Compound to increase flowability of mixture, assist in dispersal of cement grains, neutralize setting shrinkage of grout.
B. Bentonite:
   1. Premium grade Wyoming sodium montmorillonite manufactured in accordance with API 13A.
      a. Grout mix: Contain no more than two percent bentonite by dry weight of cement.
C. Water: Fresh and potable water.
D. Admixtures:
   1. Contractor’s option as necessary to improve pumpability, to control set time, and to prevent segregation and bleeding.
   2. Admixtures shall be non-toxic and biodegradable and conform to ASTM C494.

2.02 EQUIPMENT
A. General:
   1. Drilling Equipment: Equipment used for drilling boreholes; lowering, raising, and rotating grout tubes; mixing grout; and injecting grout, shall have proven performance for use in performing Permeation Grouting.
   2. Drill bits shall be capable of advancing through ground conditions indicated.
   3. Spare parts and equipment shall be available on Site to maintain the grouting equipment in satisfactorily operating condition at all times during execution of the Ground Treatment work.
B. Permeation Grouting:
   1. Grout Mixer:
      a. The grout mixer shall be mechanically driven, capable of effectively mixing and stirring grout mixes with water-cement rations between 0.6:1 and 6.0:1 measured by volume,
b. Mixing shall be achieved by constant rapid circulation of grout. Low-speed paddle-type of mixers will not be permitted.

c. The mixer shall be equipped with a suitable water-measuring device calibrated to read in cubic feet and tenths, and so designed that after each delivery the hands can be conveniently set back to zero.

2. Agitated Sump:

a. The agitated sump shall be mechanically driven and so designed as to be capable of effectively stirring and holding in suspension all solid matter in the grout.

b. The agitated sump shall have a minimum capacity of 10 cubic feet of grout.

c. The agitated sump shall be equipped with a device for accurately measuring the volume of grout at any given time, to an accuracy of 0.1 cubic foot.

3. Grout Pump(s):

a. Grout pump(s) shall be capable of pumping at minimum rates and pressures required to perform the work. Distribution of grout, under pressure, to the grouting location shall be monitored by separate, automatic recording flow rate indicators, totalizers, and pressure gauges.

4. Other Equipment:

a. Grout lines used between the grout pump and the header and back to the agitator sump shall not be less than 1-1/2 inch inside diameter and capable of withstanding the maximum grouting pressure with ample margin of safety.

b. Pressure gages shall be calibrated with not greater than 2 psi divisions on the dial.

c. A “mud balance” calibrated to read in pounds per cubic foot shall be furnished and maintained at each batching and agitation setup.

PART 3 - EXECUTION

3.01 GENERAL

A. Ground Treatment shall be completed at least 30-days prior to excavating in designated areas.

B. Contain excess grout and soil from Ground Treatment operations in mud tanks or by other approved methods to facilitate rapid cleanup at the end of each shift at a minimum.

C. Place equipment for mixing, holding, and pumping grout in a secure location and prevent spillage of material.

D. Do not discharge water, waste, grout, or soil outside the confines of the work site including into any surface water or storm drain system.
E. Thoroughly clean site and contain and dispose of all debris, water, waste grout, and spilled material at the completion of daily grouting operations.

F. Dispose of waste per Section 01 74 00, Cleaning and Waste Management.

G. Environmental Management:

1. Meet all water discharge requirements per Section 01 57 13, Temporary Erosion and Sediment Control, and Section 01 57 24, Temporary Site Water Discharge.

3.02 GROUTING REQUIREMENTS

A. General:

1. Drilling/grouting rods shall be of sufficient stiffness to ensure that the deviation of drilling locations from the theoretical axis is no greater than one foot.

2. Grout injection rate shall be monitored by counting the strokes of the piston pump in a fixed period of time if piston displacement calibration is available or by using a flow meter.

3. Grout injection pressures shall be monitored with calibrated pressure gauges mounted on the injection lines. Prior to the start of each injection, check to verify that there is no blockage in the grout injection equipment.

B. Grout Mixing:

1. The method of injection for cement grouting shall be continuous mixing method, with the proper amounts of cement, sand, water, and additives automatically proportioned and continuously supplied at proper flow rates and pressures.

2. A sampling cock, to allow frequent set time checks, shall be placed after the baffling chamber.

3. Suitable check valves shall be placed in the grout lines at the proper locations to prevent backflow.

C. Injection Procedures:

1. Using double packers, cement grout shall be injected into the design zones through grout ports in the sleeve pipes.

2. The grouting pressure for any one pipe shall not be more than 2 psi per foot of overburden.

3. Temporary, very high injection pressures will be permitted to crack open sleeve-ports, but these pressures will not be permitted for longer than one minute duration.

4. The rate of injection into any port shall not exceed three gallons per minute.

5. Adjust injection procedures as needed to prevent surface heave or prevent overstress of adjacent structures.

6. Grouting shall be considered complete at any hole when theoretical target volumes have been reached for each hole.

D. Set Times:
1. All grouts shall have a set time between 5 minutes and 50 minutes, with most grout having set times in the range of 20 minutes to 40 minutes.

2. Samples shall be obtained for set time checks at least four times per hour of pumping or for every 1,000 gallons of grout, whichever is more.

E. Post Grouting Procedures:

1. After the grout has set, cut off grout pipes a minimum of 18 inches below ground surface, backfill with grout and repair ground surfaces to pre-existing conditions or better.

2. Abandon pipe in accordance with WAC 173-100.

3.03 GROUT MIXING

A. Mixing plant (Plant) shall be used for the preparation of the grout.

B. Plant shall consist of high-speed grout mixer, grout agitator, grout pumps and control unit, as required.

C. Plant shall be capable of supplying a uniform grout mixture in the quantities required for timely execution of the work.

D. If bentonite is used, add bentonite to water and mix thoroughly to hydrate prior to adding cement.

3.04 CLEANUP AND DECOMMISSIONING

A. Complete cleanup of the work area daily upon completion of grouting operations.

B. Dispose of grout in accordance with all required state and federal environmental regulations.

3.05 DAILY SHIFT REPORTS

A. Grouting:

1. Include all the following information daily for each injection grout hole:

   a. Number and classification of labor and equipment used.

   b. Quality control sampling and measurements for grouting operations.

   c. Nature, causes, duration, and impacts from interruptions and delays during the shift.

   d. Start and finish times.

   e. Limits, including depth and width, of grout injection.

   f. Grout mix data.

   g. Grout injection rate and volumes injected.

   h. Injection pressures.

   i. Grout leakage.
j. Ground heave.
k. Grout hole geometry including location, spacing, depth, and casing details.
l. Inclination.
m. Test samples taken.

3.06 RECORD DOCUMENT DRAWINGS
A. See Section 01 78 39, Project Record Documents.
B. Identify coordinates (x, y, z) of Ground Treatment areas.
C. Submit mark-up drawings within 30 days of completion of work at each Ground Treatment location.

3.07 FIELD QUALITY CONTROL
A. Check condition of completed Ground Treatment.
   1. Drill a minimum of two core holes from the ground surface or excavation face. Obtain continuous core samples from within the grouted zone.
   2. If horizontal holes are used, drill core holes through the excavated face to a maximum length equal to two thirds the distance of the Ground Treatment beyond the shaft wall surface.
   3. For horizontal holes, groundwater inflow rates for each core hole shall be measured and recorded. Where inflows exceed 0.25 gallons per minute the ground treatment zone does not conform to design criteria. Perform additional measures to decrease the permeability of the Ground Treatment.
   4. Observe the recovered cores. If ungrouted zones in excess of 6 inches are observed, perform additional measures to provide a uniform grouted zone.
   5. All core holes shall be fully grouted on completion.
B. Where a condition develops that is likely to endanger the stability of the excavation or adjacent structures, a full crew shall operate 24 hours a day, including weekends and holidays, until those conditions no longer jeopardize the stability of the work.
CONTRACT SPECIFICATIONS

SECTION 31 32 36
SOIL NAILING

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.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections not referenced below may also be related to the proper performance of this work.

1. Section 01 45 00, Quality Control.
2. Section 03 05 15, Portland Cement Concrete.
3. Section 03 37 13, Shotcrete.
4. Section 06 82 00, Glass-Fiber-Reinforced-Plastic.
5. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

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 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, 60,000 PSI Tensile Strength

d. ASTM A615 Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

e. ASTM A722 Standard Specification for Uncoated High-Strength Steel Bar for Pre-stressing 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 Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

4. FHWA IF-03-017 Geotechnical Circular No. 7, Soil Nail Walls.

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.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Manufacturer's product data for manufactured products indicated.

C. Soil Nail Construction Work Plan:

1. At least 21 days prior to initiating the work.

2. In accordance with Section 01 45 00, Quality Control.
D. Qualifications.

E. Certifications.

F. Soil Nail Test Results.

G. Soil Nail Installation Records

1.05 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 structural 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 geotechnical engineer currently registered in the State of Washington, with a minimum of five years of experience in monitoring and testing programs 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 percent of the applied loads.

4. Manufacturer certification for nail couplers and bar centralizers.

1.06 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. Show location of existing utilities based on field surveys.

4. Indicate locations of sheet drains, drain grates, and other appurtenances.
5. 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 and 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, 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.


8. Shotcrete installation procedures, in accordance with Section 03 37 13, Shotcrete.

1.07 SOIL NAIL INSTALLATION AND TEST RECORDS

A. Installation records shall include:

1. Head location.

2. Length of installed nail.

3. Bar type.

4. Soil conditions encountered during installation.

5. Grout mix, pressure, and volume.

B. Test records shall include:

1. Testing procedures.

2. Testing results.
C. Installation and Test records shall be prepared by the independent Geotechnical Engineer and submitted to the Resident Engineer for approval.

1.08 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 Publication No. FHWA IF-03-017 Geotechnical Circular No. 7, Soil Nail Walls.
   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 approved methods.

D. Soil Parameters:
   1. For soil properties see the N120 Geotechnical Baseline Report.
   2. For jet grout improved soil areas see Section 31 32 13.36, Jet Grouting Soil Stabilization.

E. Minimum Utility Clearance:
   1. 3 feet below and 5 feet above all utilities.

F. Facing:
   1. For shotcrete Facing:
      a. Design in accordance with Section 03 37 13, Shotcrete, FHWA IF-03-017 Geotechnical Circular No. 7, Soil Nail Walls, and ACI 318.
      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 Section 03 37 13, Shotcrete.

C. Soil Nail Grout: Neat or sand/cement mixture with:
   1. Cement: ASTM C150, Type II, Low Alkali.
   2. Aggregates: ASTM C33 and Section 03 05 15, Portland Cement Concrete.
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 in section 06 82 00, Glass-Fiber-Reinforced-Plastic.

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 25 mils.
      e. Pre-grouted per manufacturer’s recommendations.
   2. Hot-Dip Galvanizing for Accessories: ASTM A123 or AASHTO M111.

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.
   2. The drainage core with the geotextile fully encapsulating the core shall have a minimum flow rate of 1 liter per second per meter 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 12 months.
      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 Section 31 09 00, Geotechnical Instrumentation Monitoring of Earthwork.
      b. Calibrated by an Independent Testing Laboratory within the last 12 months.
   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.

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 required in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork. Notify Resident Engineer if new cracks develop in the existing structures. Limit vertical and horizontal movements as specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork, 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 in accordance with 01 45 00, Quality Control. 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.

3.04 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. First lift wall face: Less than 8 hours or as approved by the Resident Engineer.
2. Subsequent lifts: Less than 16 hours, unless ground conditions are suitable for longer duration closure times, as approved by the Resident Engineer.
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.

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 are not permitted for drill holes.

C. A licensed, Professional Land Surveyor shall locate all soil nails prior to drilling.

D. 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 immediately and notify the Resident Engineer.

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. 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.

B. 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.
3.09 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.

3.10 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.

3.11 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 should not affect the location of the reinforcing steel under the bearing plate.

3.12 VERIFICATION TESTING
A. Perform two verification tests prior to installation of production nails to verify installation methods, soil nail pullout capacity, and design assumptions. 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. Use an unbonded length of the test soil nail of at least 3 feet unless approved otherwise. Determine the bonded length of the soil nail based on grade and size such that the allowable bar load is not exceeded; 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.

D. Determine the Design Test Load (DTL) by multiplying the bond length of the nail by the applicable bond strength as specified below:

1. Allowable Bond Strength:
a. Fill: 2.0 kip per linear foot.

b. Till and Jet Grout Improved areas: 5.0 kip per linear foot.

E. During Verification testing, incrementally load test soil nails in accordance with the following schedule:

<table>
<thead>
<tr>
<th>LOAD</th>
<th>HOLD TIME</th>
<th>LOAD</th>
<th>HOLD TIME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment Load (AL)</td>
<td>1 Minute</td>
<td>1.75 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>0.25 DTL</td>
<td>10 Minutes</td>
<td>1.50 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>0.50 DTL</td>
<td>10 Minutes</td>
<td>1.25 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>0.75 DTL</td>
<td>10 Minutes</td>
<td>1.00 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>1.00 DTL</td>
<td>10 Minutes</td>
<td>0.75 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>1.25 DTL</td>
<td>10 Minutes</td>
<td>0.50 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>1.50 DTL</td>
<td>60 Minutes</td>
<td>0.25 DTL</td>
<td>Until Stable</td>
</tr>
<tr>
<td>1.75 DTL</td>
<td>10 Minutes</td>
<td></td>
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</tr>
<tr>
<td>2.00 DTL</td>
<td>10 Minutes</td>
<td></td>
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</tr>
</tbody>
</table>

F. For the alignment load (AL), the minimum load required to align the testing apparatus, do not exceed 0.05 DTL. Reset dial gauges to zero after the alignment load has been applied.

G. Hold each load increment for at least 10 minutes. Monitor the verification test nail for creep for 60 minutes at 1.50 DTL load increment. Measure nail movement during the creep portion of the test and record at 1, 2, 3, 5, 6, 10, 20, 30, 50, and 60 minutes.

3.13 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. Incrementally load soil nail in 0.25 DTL increments to a maximum load of 1.50 DTL. Hold each load increment until the dial gage reading is stable.

C. For the alignment load (AL), the minimum load required to align the testing apparatus, do not exceed 0.05 DTL. Reset dial gauges to zero after the alignment load has been applied.

D. Maintain all increments within 5 percent of the intended load. Depending on performance, perform either a 10-minute or 60-minute creep test at 1.50 DTL. Measure nail movement and record at 1, 2, 3, 4, 6 and 10 minutes. Where the nail movement between 1 minute and 10 minutes exceeds 0.04 inch, maintain the maximum load an additional 50 minutes and record the movements at 20, 30, 50, and 60 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.
3.14 TEST NAIL ACCEPTANCE CRITERIA

A. Test nails will be considered acceptable when:

1. For verification tests, a creep rate less than 0.08 inch per log cycle of time between the 6 and 60 minute readings 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, or a creep rate less than 0.08 inch per log cycle of time between the 6 and 60 minute readings, 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.

3.15 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 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.

3.16 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.

3.17 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.
3.18 FACING INSTALLATION

A. Install shotcrete facing as indicated on the Contract Drawings, and conforming to requirements of Section 03 37 13, Shotcrete.

3.19 PREPARATION OF HEADWALL FOR TUNNEL BORING MACHINE (TBM) RECEPTION AT BROOKLYN STATION

A. Stitch drill, or saw cut the TBM profiles at least 1 week prior to the TBMs receptions.

B. Ensure TBM profiles are cut to a depth sufficient to ensure clean receptions and minimize disturbance of adjacent headwall facing.

C. Incorporate adequate tolerance for TBM reception when laying out the cut.

END OF SECTION
PART 1 - GENERAL

1.01 DESCRIPTION:
A. This Section includes specifications for designing, furnishing, installing, monitoring, and leaving in place. Locations and extent of these systems are shown on the Contract Drawings.

B. This section applies to both owner-designed excavation support systems (Contract Drawings) and Contractor-designed excavation support systems (Working Drawings). Design requirements that apply only to Contractor-designed excavation support systems are noted accordingly.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 03 05 15, Portland Cement Concrete
   2. Section 05 12 00, Structural Steel Framing
   3. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
   4. Section 31 20 00, Earth Moving.
   5. Section 31 23 19, Dewatering.
   6. Section 31 51 00, Anchor Tiebacks

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
      a. ASTM A36 Standard Specification for Carbon Structural Steel
      c. ASTM A328 Specification for Steel Sheet Piling
      d. ASTM A500 Standard Specifications for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes.
      e. ASTM A572 Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
   2. American Wood Preservers’ Association (AWPA):

1.03 DEFINITIONS

A. Anchor Tieback: Refer to 31 51 00, Anchor Tiebacks.

B. Design Load: The calculated load.

C. Drainage Mat: A manufactured material available in sheets or rolls used behind lagging to prevent buildup of hydrostatic pressure.

D. Cutter Soil Mixing (CSM): Deep soil mix panel constructed by mixing a cementitious binder with in-situ soil to form a soilcrete panel cut wall.

E. Existing Construction: Adjacent structures, facilities, equipment, conveyances, and utilities present at the beginning of excavation.

F. Lagging: A horizontal element restraining the lateral movement of a cut soil face and supported by soldier piles or wales. Lagging is typically timber, precast concrete, or shotcrete.

G. Parcel: An area of ground as indicated, including all existing construction upon or connected to it.

H. Raker: A sloping strut, typically supported on grade.

I. Restore: To return to pre-excision condition by repair or replacement of portions damaged, altered, or removed by excavation activities.

J. Sheet: A vertical element restraining the horizontal movement of a cut soil face and supported by soldier piles or wales. Sheets are typically flat steel plates and do not provide water cutoff.

K. Sheet Pile: A vertical element restraining the horizontal movement of a cut soil face and supported by wales. Sheet piles are typically interlocking profiled steel plate shapes and provide water cutoff.

L. Shore: A horizontal, inclined, or vertical element positioned against or beneath a structure, part of a structure, or utility to restrain movement.

M. Shoring: An excavation support system designed and installed to protect the public and property from potential impact due to excavation activities by limiting the horizontal and vertical movement of soil and adjacent construction. Shoring may be temporary or permanent.

N. Soldier Pile: A vertical element supporting lagging and supported by embedment into grade and tieback anchors, wales, struts, or rakers. Soldier piles are typically rolled steel W-, S- or H-shapes

O. Strut: A horizontal element keeping two other elements a fixed distance apart, usually soldier piles or wales. Struts carry axial compression and are typically rolled steel pipe, tube or W-, S-, or H-shapes.

P. Tangent Pile: A vertical element restraining the horizontal movement of a cut soil face and supported by embedment into grade and tieback anchors, wales, struts, or rakers. Tangent piles are typically drilled concrete piles set with no space between adjacent piles and reinforced with deformed bars or rolled steel W-, S-, or H-shapes.
Q. Tremie: A pipe used to place concrete under water or slurry, displacing the water or slurry during placement.

R. Tremie Concrete: Concrete placed under water or slurry using a tremie.

S. Underpinning: A vertical element supporting the vertical and horizontal load of a structure, part of a structure, or utility.

T. Wale: A horizontal element supporting lagging, sheets, sheet piling, or soldier piles, and supported by anchor tiebacks or struts.

U. Working Drawings: Drawings describing the excavation support system for Contractor-designed systems.

1.04 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Driller’s Qualifications.

C. Structural engineer’s Qualifications: For Contractor-designed excavation support systems.

D. Surveyor’s Qualifications.

E. Welder Certifications.

F. Construction Work Plan: Submit a written program. Include descriptions of the following:
   1. Installation procedures
   2. Drilling equipment
   3. Excavation sequence and schedule
   4. Shaft excavation methods, including drilling methods, methods for cleanout of shafts, and disposal plan for excavated material and drilling slurry (if applicable).
   5. Methods to be used to ensure shaft stability, such as temporary casing or slurry.
   6. Interface details for existing construction
   7. Protection measures for existing construction
   8. Instrumentation and monitoring procedures
   9. Removal procedures and sequence
   10. Contingency plans for excessive shoring movements as discussed under Excavation Support System Performance Criteria in Part 1, herein.
   11. Field quality control measures

G. Working Drawings: For excavation support system designed by the Contractor, submit Working Drawings signed and sealed by a structural engineer. Include the following:
   1. Element sizes and locations
   2. Element assembly and connection details
3. Interface details for existing construction
4. Interface details for permanent elements

H. Calculations.
I. Structural Steel Shop Drawings: Submit in accordance with 05 12 00, Structural Steel Framing.
J. Soldier Pile Logs: Include for each pile:
   1. Pile number, location, size, and location of splices, if present.
   2. Date and time of start and completion of pile shaft excavation
   3. Elevation of water table during excavation.
   4. Soil conditions encountered during drilling.
   5. Pre-bored hole diameter, and any variations in diameter with depth.
   6. Concrete mix data including design mix number, volume placed, and method of placement.
   7. Date and time of installation of concrete encasement.
   8. Pile plumbness.
   9. Final top and bottom elevations of pile and concrete encasement.
   10. Final horizontal location of pile axis, and variation from design location.
   11. Other documentation as may be dictated by construction conditions including problems encountered, and delays.
K. Mix Designs: Submit mix designs for all concretes and grouts.
L. Monitoring Program Readings and Results.

1.05 QUALITY ASSURANCE
A. Driller: Select drillers having a minimum of 5 years of experience in preboring holes for soldier piles or work of similar character.
B. Structural Engineer: For Contractor-designed excavation support systems, select a licensed civil or structural engineer currently registered in the State of Washington, with a minimum of 5 years of experience in the design and construction of excavation support systems.
C. Professional Land Surveyor: Select a licensed professional land surveyor currently registered in the State of Washington, with a minimum of 5 years of experience in work of a similar character.
D. Welders: Certified as described in 05 05 23, Metal Fastenings.

1.06 EXCAVATION SUPPORT DESIGN REQUIREMENTS
A. Excavation support systems designed by the Contractor shall meet the following criteria:


3. Support earth pressures indicated on Contract Drawings, including surcharge loads due to existing construction, equipment, traffic, and construction activities.

4. Driving of soldier piles or sheet piles with vibratory or impact hammers is not allowed.

5. Allow the required free excavated space for workers and groundwater control systems.

6. Conform to excavation and backfill sequences as indicated in the Construction Work Plan.

7. Design excavation support systems such that the deflections are less than those specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork or indicated on the contract drawings.

8. Compatible with conditions described in the Geotechnical Baseline Report.

1.07 CONTINGENCY REQUIREMENTS

A. Contingency Plan: Have materials and equipment readily available to implement mitigating measures to arrest potential excavation support movement. Mitigating measures shall be approved by the Resident Engineer. For the station box excavation, have on hand at least one supplemental strut and one supplemental wale of similar size and length to those shown on the contract drawings.

B. If the 1 inch deflection criteria is exceeded:

1. Notify the Resident Engineer immediately.

2. Increase frequency of readings and/or furnish and install additional instrumentation and monitoring points as determined by the Resident Engineer.

3. Implement mitigating measures if directed by the Resident Engineer and be prepared to terminate construction activities in the area.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Materials for excavation support systems may be new or used, provided they are sound and free from strength-impairing defects.

B. Concrete: Refer to Section 03 11 00, Concrete Forming, Section 03 20 00, Concrete Reinforcing, Section 03 30 00, Cast-In-Place Concrete, Section 03 37 13, Shotcrete and Section 03 05 15, Portland Cement Concrete, for requirements.

C. Grout: Refer to Section 03 62 00.

D. Metals: Refer to Section 05 12 00 Structural Steel Framing.
E. Tiebacks: Refer to Section 31 51 00, Anchor Tiebacks.

F. Timber:
   1. Grade: As specified on the Contract Drawings or approved Working Drawings.
   2. Lagging: Lagging shall be rough-sawn. Lagging need not be new, but shall be in serviceable condition.
   3. Preservative Treatment: Pressure treat wood members left in place with preservative material in accordance with AWPA U1, Use Category 4A, Commodity Specification A.

G. Do not use combustible waste or similar material for packing or soil retention in excavations.

PART 3 - EXECUTION

3.01 GENERAL
A. Construct excavation support systems in accordance with Contract Drawings or approved Working Drawings and in a manner that will ensure that supported faces will be stabilized.

3.02 FIELD QUALITY CONTROL
A. Monitoring Program: Monitor the excavation support at the locations indicated. Monitor in accordance with Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

B. Excavation Support System Installation: Retain the services of a geotechnical engineer to observe the installation.

C. Concrete and Grout Testing: Test concretes and grouts in accordance with Section 03 05 15, Portland Cement Concrete.

D. Utility Locations:
   1. Utilities in close proximity to soldier piles shall have their locations and depths verified by potholing prior to the start of soldier pile drilling. Refer to the shoring plan for the minimum utilities that need to be pothed, although the Contractor shall pothole any utilities that appear to be in potential conflict with the shoring. Representatives of SDOT and the utility owner will need to be present at the time of potholing, so notify them at least 10 days prior to potholing.
   2. Proceed with caution in areas of utility facilities and structures. Expose existing utilities by hand-excavation or by other method acceptable to the utility owner.
   3. If existing utility facilities and structures interfere with proposed method of excavation support, modify or relocate such facilities in accordance with the utility owner's recommendations or modify the excavation support systems.

3.03 SOLDIER PILES
A. SEQUENCING AND SCHEDULING
1. Sequence pile installation such that no pile is excavated within a clear distance of 12 feet from concrete encasement less than 12 hours old.

2. Schedule work so that encasement is placed within twelve hours after excavation of pile.

3. Place soldier pile and concrete encasement immediately after excavation bottom is inspected and accepted.

B. EXCAVATION FOR SOLDIER PILES

1. Drilling: Observe the drilling rate and resistance as the boring of each hole is advanced. Record the relative drilling rate.

2. Temporary Casing
   a. Pre-bored holes may require casing through soil to prevent collapse of overburden and control seepage water. The cost of any casing shall be incidental to the excavation support system.
   b. Install temporary casing if required, sufficient to withstand handling stresses, concrete pressure, and surrounding earth and water pressures.
   c. Leave the casing in place through the cleaning and inspection operations of the pre-bored holes. Withdraw casing as the concrete is placed.
   d. Begin extraction of casing only after sufficient concrete has been placed in the shaft to achieve a minimum height differential between the bottom of the casing and the top of concrete of 5 feet. Maintain the differential until the concrete achieves finish elevation.

3. Groundwater Control
   a. In the event that groundwater is encountered during excavation operations, pumping of water from the pile excavation will be permitted during construction, provided that the groundwater does not flow into the excavation rapidly enough to carry particles of soil or result in caving of excavation walls, bottom heaving, or ground settlement.
   b. If groundwater inclusion endangers the stability of the excavation or adjacent structures, or exceeds reasonable pumping capacity, take such groundwater control measures as may be required in accordance with applicable regulations.
   c. Monitor and discharge groundwater in accordance with Section 31 23 19, Dewatering.

4. Cleaning and Inspecting Pre-bored Holes
   a. After the holes have been bored to the proper depth, remove loose earth or debris, including water, from the bottom and sides of the hole. Leave bottom surfaces flat and level.
   b. Measure drilled holes to verify the piles have been drilled to the depths indicated on the Contract or approved Working Drawings.

5. Do not allow vibration or excessive wheel loads within the immediate vicinity of any pile. Maintain drill hole excavation stability at all times.
C. INSTALLATION OF SOLDIER PILES

1. Place the steel soldier piles and maintain in the center of the pre-bored hole using centering devices. Align the flange of the pile parallel to the future excavation line.

2. Cutting Off Steel Soldier Piles
   a. For pile installation where a longer pile than required was furnished, cut off the pile to the length required.
   b. Make the cut at the location necessary to maintain the tieback openings at the levels shown on the Contract Drawings or approved Working Drawings.
   c. Make all cuts perpendicular to the axis of the pile.
   d. Remove cut off sections of steel soldier piles from the site and suitably dispose of.

3. Rebuilding or Extending Steel Soldier Piles
   a. Extend the soldier pile installations where the depth of the pre-bored holes must be extended beyond the depth shown on the Contract Drawings or approved Working Drawings to obtain a non-yielding foundation for the pile, and where the length of the furnished pile is inadequate for the deepened hole.
   b. Provide the length of extension necessary to extend the soldier pile to the bottom of the pre-bored hole, while maintaining the tieback openings at the levels shown on the Contract Drawings or approved Working Drawings.
   c. Provide extensions of the same section size and weight as the soldier pile to which it is spliced.
   d. Submit splicing details to the Resident Engineer.

D. PLACEMENT OF CONCRETE ENCASEMENT

1. Place concrete encasement in accordance with Section 03 30 00, Cast-In-Place Concrete, and the following requirements:
   a. Place concrete in dry excavations whenever practicable. Use all practicable means to obtain a dry excavation before and during concreting.
   b. Place concrete for dry excavations by free fall or tremie methods. Place concrete equally around the steel soldier pile. Place concrete in each pile continuously to the top elevation.
   c. If water accumulates in the pre-bored holes after cleaning and inspection prior to concrete encasement remove water by approved methods, or place the concrete below the accumulated water using tremie methods
      1) When the groundwater infiltration rate is greater than 1/4-inch vertical rise in hole per minute, consider soldier pile excavations "wet" and place concrete using the tremie method.
2) Except when concreting by the tremie method, do not allow the total height of water in the bottom of the excavation to exceed 2 inches at the time of concrete placement.

2. Remove the temporary casing, if present. During extraction of the casing, prevent upward movement of the steel soldier pile.

3. Vibrate only the top 5 feet of concrete after the casing has been withdrawn.

3.04 CUTTER SOIL MIXING
A. SEQUENCING AND SCHEDULING

B. PANEL CONSTRUCTION

C. INSTALLATION OF SOLDIER PILES

3.05 LAGGING
A. Install lagging as excavation progresses.

B. Do not allow more than four feet of exposed cut soil face.

C. Backfill lagging with free-draining material as lagging is installed. Backfill lagging prior to excavating subsequent lift.

D. Take immediate steps to prevent piping of soils through lagging if observed.

3.06 SUPPORT SYSTEMS WITH INTERNAL BRACING
A. General: Provide wales, struts, and rakers as necessary to support excavation faces retained by soldier piles and lagging.

B. Bracing:
   1. Provide wales where required, at each level of bracing. As excavation proceeds, place wales on open face of support system wall. Wedge, dry pack, and otherwise provide tight bearing between wales and support system wall, with ample bearing areas to provide uniform transfer of loads.

   2. Include web stiffeners, plates, angles, or bracing as needed to prevent rotation, crippling, or buckling of connections and points of bearing between structural members. Allow for eccentricities caused by field fabrication and assembly.

   3. Design bracing support members for maximum loads which may occur during excavation and removal stages.

3.07 PILE BRACING
A. Steel bracing may be required during tieback stressing and testing to restrain the soldier pile from twisting. The locations and configuration of the bracing will be determined in the
field at the time of construction. The cost to furnish the bracing will be considered incidental.

3.08 EXCAVATION BELOW TIEBACKS AND BRACING

A. Tieback, wale, strut and raker installation testing and stressing shall be completed prior to excavating more than 3 feet below centerline of tieback or bracing level.

3.09 TOLERANCES

A. Soldier Piles:

1. Install tops of soldier piles within 1 inch, plus or minus, horizontally of the locations shown on the approved Working Drawings or Contract Drawings.

2. Install tops of soldier piles within 1 inch, plus or minus, vertically of the locations shown on the approved Working Drawings or Contract Drawings.

3. Install steel soldier piles within 0.5 percent of plumb.

B. CSM

1. Install tops of soldier piles within 1 inch, plus or minus, horizontally of the locations shown on the approved Working Drawings or Contract Drawings.

2. Install tops of soldier piles within 1 inch, plus or minus, vertically of the locations shown on the approved Working Drawings or Contract Drawings.

3. Install steel soldier piles within 0.5 percent of plumb.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing, maintaining, and leaving in place a temporary tieback retaining wall as indicated on the Contract Drawings. Coordinate requirements of this Section with Section 31 50 00, Excavation Support and Protection.

B. Unless otherwise directed, the Contractor shall select the tieback type, drilling method, grouting method, grouting pressures, and, subject to the minimum values in the Contract Drawings, determine the bond length, free-stressing (unbonded) length, and anchor diameter. The Contractor shall be responsible for installing tiebacks that will develop the load-carrying capacity indicated on the Contract Drawings in accordance with the testing subsection of this Specification.

C. The work of this Section includes the following:

1. Install temporary tiebacks as required as excavation proceeds.

D. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete.
2. Section 03 11 00, Concrete Forming.
3. Section 03 20 00, Concrete Reinforcing.
4. Section 03 30 00, Cast-In-Place Concrete.
5. Section 31 50 00, Excavation Support and Protection.
6. Section 01 74 01, Excavation Spoils and Muck Disposal.

1.02 REFERENCES

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

   b. ASTM A500 Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
   c. ASTM A775 Standard Specification for Epoxy-Coated Steel Reinforcing Bars
d. ASTM A779 Standard Specification for Steel Strand, Seven-Wire, Uncoated, Compacted, Stress-Relieved for Prestressed Concrete

e. ASTM A882 Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand


g. ASTM D1248 Standard Specification for Polyethylene Plastics Extrusion Materials For Wire and Cable


i. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

j. ASTM D4101 Standard Specification for Polypropylene Injection and Extrusion Materials

2. American Association of State Highway and Transportation Officials (AASHTO):

a. AASHTO M85 Portland Cement

b. AASHTO M183 Structural Steel

c. AASHTO M203 Steel Strand, Uncoated Seven-Wire for Concrete Reinforcement

d. AASHTO M222 High-Strength Low-Alloy Structural Steel with 50 ksi Minimum-Yield Point to 4-in Thick

e. AASHTO M252 Corrugated Polyethylene Drainage Pipe

f. AASHTO M275 Standard Specification for Uncoated High-Strength Steel Bar for Prestressing Concrete

g. AASHTO M284 Standard Specification for Epoxy-Coated Steel Reinforcing Bars

3. Post-Tensioning Institute (PTI):

a. Recommendations for Prestressed Rock and Soil Anchors

b. Post-Tensioning Manual

1.03 DEFINITIONS

A. Anchor Tieback: System used to transfer tensile loads to soil or rock. Includes all prestressing steel, centralizers, spacers, anchorage devices, grout, coatings, sheathings, corrosion protection, and couplers if used, and final concrete facing.

B. Soldier Piles: See 31 50 00, Excavation Support and Protection.

C. Tremie Concrete: see Section 31 66 17, Slurry Diaphragm Walls.

D. Wale: See 31 50 00, Excavation Support and Protection.
E. Alignment Load: A nominal minimum load applied to an anchor tieback during testing to keep the testing equipment correctly positioned.

F. Bondbreaker: A sleeve placed over the tendon in the unbonded length to ensure unobstructed elongation of the tendon during stressing.

G. Encapsulation: A corrugated or deformed tube protecting the prestressing steel against corrosion.

H. Tendon: The complete anchor assembly (excluding grout) including prestressing steel (strands or bar), corrosion protection, sheathings, coatings, and spacers and centralizers.

I. Bond Length: The length of the anchor tieback that is bonded to the surrounding soil and capable of transmitting the applied tensile load to the soil.

J. Tendon Bond Length: The length of the tendon that is bonded to the surrounding grout and capable of transmitting the applied tensile load to the grout.

K. Unbonded Length: The designed length of the tendon that is not bonded to the grout during stressing.

L. Working Drawings: See 31 50 00, Excavation Support and Protection.

M. Centralizers: Support the tendon in the drill hole and position the tendon so grout freely flows around tendon and up drill hole.

N. Spacers: Separate the steel strands of strand tendons.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit calculations for design of the tendons, unbonded lengths, bonded lengths, bearing plates, bearing stiffeners, and wedge plates for review and approval prior to commencement of this work. Ensure calculations are prepared, sealed, and signed by an anchor tieback design engineer.

C. Working Drawings indicating tieback system and installation procedures. Include:

1. Anchor tieback schedule showing each anchor tieback number, design load, tendon type, anchor diameter, minimum bond length, minimum tendon bond length, and minimum unbonded length.

2. Details for spacers and locations, centralizers, anchorage and trumpet.

D. Grout mix design.

E. Mill test reports for prestressing steel and bearing plate steel.

F. Calibration data for each test jack, load cell, primary pressure gage, and reference pressure gage to be used. Calibration records shall include the date tested, the device identification number and the calibration test results, and shall be certified for an accuracy of at least 2 percent of the applied certification loads by a qualified independent testing laboratory within 90 days prior to submittal.

G. Grouting records indicating cement type, quantity injected, and grout pressures; anchor test results and graphs, and as-bUILts showing location and orientation of each anchor.
tieback, capacity, tendon type, total anchor length, bond length, and locations of all instruments.

H. Test data and results for all testing required herein.

I. Driller’s qualifications.

J. Anchor Tieback Design Engineer’s qualifications.

1.05 QUALITY ASSURANCE

A. Drillers shall be skilled in tieback installation work, for the purpose of drilling and installing tiebacks, and have a minimum of five years of experience in drilling and installing work of similar scope and complexity.

B. Anchor Tieback Design Engineer shall be a professional civil or structural engineer currently registered in the State of Washington.

1.06 DELIVERY, STORAGE, AND HANDLING

A. Handle and store tendons in such a manner as to avoid damage or corrosion. Damage to prestressing steel as a result of abrasions, cuts, nicks, welds, and weld spatter will be cause for rejection.

B. Protect prestressing steel if welding is to be performed in vicinity. Grounding of welding leads to prestressing steel is forbidden. Protect prestressing steel from dirt, rust, deleterious substances, or excessive heat. A light coating of rust on steel is acceptable. If heavy corrosion or pitting is noted, Resident Engineer will reject affected tendons.

C. Do not cause excessive bending during lifting of pre-grouted tendons, which can de-bond the prestressing steel from the surrounding grout.

D. Tendon bond length must be free of dirt, manufacturer’s lubricants, and corrosion inhibiting coatings or other deleterious substances that may significantly affect the grout tendon bond.

1.07 PROJECT CONDITIONS

A. Refer to Geotechnical Baseline Report.

B. Existing Utilities: Verify location of existing utilities prior to commencement of excavation activities. Proceed with caution in areas of utility facilities and structures. Expose existing utilities by hand-excavation or by other method acceptable to the utility owner.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Use new materials that are sound and free from strength-impairing defects.

B. Soldier Piles: In Accordance with Section 31 50 00, Excavation Support and Protection.

C. Steel Wales: In Accordance with Section 31 50 00, Excavation Support and Protection.

D. Anchorage Devices:
1. Stressing Anchorages: Combination of either a steel bearing plate with wedge plate and wedges, or a steel bearing plate with a threaded anchor nut. The steel bearing and wedge plate may also be combined into a single element. Ensure anchorage devices are capable of developing 95 percent of the specified minimum ultimate tensile strength of the prestressing steel tendon. Ensure anchorage devised conforms to the static strength requirements of the PTI Post Tensioning Manual.

2. Bearing Plates: Conform to the requirements of AASHTO M183 or M222 or equivalent.

E. Wedges: Design to preclude premature failure of prestressing steel due to notch or pinching effects under static and dynamic strength requirements of the PTI Post-Tensioning Manual. Do not reuse wedges.

F. Bondbreakers: Fabricate from smooth plastic tube or pipe having the following properties:
   1. Resistant to chemical attack from aggressive environments, grout or corrosion inhibiting compound;
   2. Resistant to aging by ultra-violet light;
   3. Fabricated from material non-detrimental to tendon;
   4. Capable of withstanding abrasion, impact, and bending during handling and installation;
   5. Enables tendon to elongate during testing and stressing;
   6. Allows tendon to remain unbonded after lock-off.

G. Cement Grout: Type I, II, III, or V portland cement conforming to the requirements of AASHTO M85. Use grout of a pumpable neat mixture of cement and water and that is stable (bleeds less than two percent), fluid, and provides a minimum 28-day compressive strength of at least 4000 pounds per square inch (psi) measured in accordance with ASTM C109 at time of stressing. Admixtures that control bleed, improve flowability, reduce water content, and retard set may be used in the grout. Ensure admixtures are compatible with the prestressing steels and mixed in accordance with manufacturer's recommendations. Expansive admixtures may only be added to grout used for filling sealed encapsulations, trumpets, and anchorage covers.

H. Centralizers and Spacers: Plastic or material non-detrimental to prestressing steel.

I. Corrosion-Inhibiting Compound: For the corrosion-inhibiting compound placed inside the sheath in the free length, use an organic compound such as wax or grease with appropriate polar moisture displacing, corrosion-inhibiting additives and self-healing properties. Use a compound that permanently stays viscous and is chemically stable and non-reactive with the prestressing steel, the sheathing materials, and the anchor grout.

J. Grout Tubes: Have adequate inside diameter to enable grout to be pumped to bottom of drill hole. Strong enough to withstand grouting pressures.

K. Prestressing Steel: Fabricate from single or multiple elements of one of the following prestressing steels:
   1. Steel bars conforming to AASHTO M275
2. Seven-wire, low-relaxation strands conforming to AASHTO M203
3. Compact seven-wire, low-relaxation strands conforming to ASTM A779

L. Couplers: capable of developing 100 percent of minimum specified ultimate tensile strength of prestressing steel bar.

M. Sheath: Use as part of the corrosion protection system for the unbonded length portion of the tendon. Fabricate from one of the following:

1. A polyethylene tube pulled or pushed over the prestressing steel. Use Type II, III, or IV polyethylene as defined by ASTM D1248, or approved equal. Use tubing that has a minimum wall thickness of 1/16 inch.
2. A hot-melt extruded polypropylene tube. Use cell classification B55542-11 polypropylene as defined by ASTM D4101, or approved equal. Use tubing that has a minimum wall thickness of 1/16 inch.
3. A hot-melt extruded polyethylene tube. Use high density Type III polyethylene as defined by ASTM D1248, or approved equal. Use tubing that has a minimum wall thickness of 1/16 inch.
4. Steel tubing conforming to ASTM A500. Use tubing that has a minimum wall thickness of 3/16 inch.
5. Steel pipe conforming to ASTM A53. Use pipe that has a minimum wall thickness of 3/16 inch.
6. Plastic pipe or tube of PVC conforming to ASTM D1784 Class 13464-B. Use pipe or tube that is Schedule 40 at a minimum.
7. A corrugated tube conforming to the requirement of the tendon bond length encapsulation.

N. Concrete and Grout: Refer to Section 03 11 00, Concrete Forming, Section 03 20 00, Concrete Reinforcing, Section 03 30 00, Cast-In-Place Concrete, and Section 03 05 15, Portland Cement Concrete, for requirements.

PART 3 - EXECUTION

3.01 GENERAL
A. Install soldier pile excavation support wall for safety and preservation of existing improvements, as specified in Section 31 50 00, Excavation Support and Protection.

3.02 FIELD QUALITY CONTROL
A. Anchor Tieback installation: Retain the services of a geotechnical engineer to observe the installation, including observation and recording of tests.

3.03 TIEBACK TENDON DESIGN CRITERIA
A. Refer to Section 31 50 00, Excavation Support and Protection, for system design requirements.
B. Determine bond length necessary to develop design load indicated on Contract Drawings or in approved working drawings. Bond length shall not be less than 10 feet.
C. Extend the unbonded length for tiebacks beyond the no load zone as shown on the Contract Drawings.

D. Anchor tiebacks shall be capable of being re-stressed as required.

3.04 FABRICATION

A. Shop or field-fabricate tiebacks. Cut prestressing steel with abrasive saw or, with approval of prestressing steel Supplier, an oxyacetylene torch. Perform pre-grouting of encapsulated tendons on an inclined, rigid frame or bed by injecting grout from low end of tendon.

3.05 INSTALLATION

A. Select the drilling method, grouting procedure, and grouting pressure to be used for installation of anchors as necessary to satisfy load test requirements.

B. Locate drill hole such that longitudinal axis of drill hole and longitudinal axis of tendon are parallel. Do not drill hole in a location that requires tendon to be bent in order for bearing plate to be connected to supported structure.

C. Prior to inserting tendon in drill hole, examine tendon for damage to encapsulation and sheathing. If required, repair encapsulation in accordance with Supplier’s recommendations. Repair damage to sheathing with high molecular weight polyethylene tape. Spiral wind the tape around the tendon to completely seal damaged area. Spiral wind at a pitch which ensures double thickness at all points.

D. Locate tendon in the middle third of the anchor section.

E. Where centralizers are required, space them at no greater than 10 feet on center with the deepest centralizer located one foot from the end of the anchor and the upper centralizer for the bond zone located no more than five feet from the top of the tendon bond length.

F. Ensure spacers permit grout to freely flow around tendon and up drill hole. Place spacers at a maximum interval of 10 feet.

G. Place tendons in accordance with recommendation of tendon manufacturer. Insert tendon in drill hole to desired depth without difficulty. Do not drive or force partially inserted tendons into drill hole. Remove tendon from drill hole and clean or re-drill the hole to permit insertion.

H. Control the rate of placement of tendon into drill hole such that sheathing and grout tubes are not damaged during installation of tendon. Do not subject anchor tendons to sharp bends. Bottom end of tendon may be fitted with a cap or bullnose to aid its insertion into the hole, casing, or sheathing.

I. Drill holes for tiebacks in a manner that will minimize loss of ground and at the locations and to the length, inclination, and diameter shown on Contract Drawings or approved working drawings.

3.06 GROUTING

A. Use a neat cement grout or sand-cement grout. Ensure cement does not contain lumps or other indications of hydration. Use grouting equipment that produces grout free of lumps and undispersed cement.
B. Use a positive displacement grout pump. Equip the pump with a pressure gage to monitor grout pressures. Ensure pressure gage is capable of measuring pressures of at least 150 pounds per square inch or twice the actual grout pressure used whichever is greater. Size grouting equipment to enable grout to be pumped in one continuous operation. Ensure mixer is capable of continuously agitating the grout.

C. Inject grout from lowest point of drill hole. Pump through grout tubes, casing, hollow-stem augers, or drill rods. Place before or after insertion of tendon. Record quantity of grout and grout pressures. Control grout pressures and grout takes to prevent excessive heave or fracturing.

D. Do not use pressure grouting in free length zone. Ensure the grout at the top of the drill hole does not contact the back of the structure or the bottom of the trumpet.

E. Clean and protect stressing tail from damage until lock-off. After anchor has been stressed and accepted by the Resident Engineer, cut tail to final length according to tendon manufacturer’s recommendations.

F. Install anchor bearing plate and anchor head or nut perpendicular to tendon, within plus or minus three degrees and centered on bearing plate, without bending or kinking of prestressing steel elements. Wedge holes and wedges shall be free of rust, grout, and dirt.

G. Dispose of spilled, discarded, and wasted grout and related materials in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.

3.07 STRESSING, LOAD TESTING, AND ACCEPTANCE OF TIEBACKS

A. Test each tieback anchor. Do not apply a load greater than 10 percent of the design load to the anchor prior to testing. Do not apply a maximum test load greater than 80 percent of the specified minimum ultimate tensile strength of the prestressing steel of the tendon. Simultaneously apply test loads to the entire tendon. Stressing of single elements of multi-element tendons is not permitted.

B. Test Equipment

1. Use a dial gage or vernier scale capable of measuring displacement to 0.001 inch to measure tendon movement. Ensure it has adequate travel so total movement can be measured without resetting the device.

2. Use a hydraulic jack and pump to apply the test load. Use the jack and a calibrated pressure gage to measure the applied load. Use a pressure gauge that is graduated in 100 psi increments or less. When the theoretical elastic elongation of the total anchor length at the maximum test load exceeds the ram travel of the jack, include the procedure for recycling the jack ram in the working drawings. Apply each increment of test load in one minute or less.

3. Maintain a calibrated reference pressure gage at the site. Calibrate the reference gage with the test jack and pressure gage.

4. Provide an electrical resistance load cell and readout when performing a creep test.

5. Place the stressing equipment over the tendon in such a manner that the jack, bearing plates, load cell, and stressing anchorage are axially aligned with the tendon and the tendon is centered within the equipment.

C. Performance Test
1. Conduct four successful performance tests on tieback anchors, as selected by the Resident Engineer. Drill and install the performance test anchors in the same manner as the production anchors, with the exception that additional or larger tendons should be included so that the test load does not exceed 80 percent of the specified minimum ultimate tensile strength of the prestressing steel of the tendon. Changes in methods, personnel, materials or equipment may require additional performance testing as determined by the Resident Engineer.

2. Performance test selected anchors as indicated in the following schedule. Raise load from one increment to another immediately after recording tendon movement.

3. Measure and record tendon movement to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment of load. Monitor load with a pressure gage. Place reference pressure gage in series with the pressure gage during each performance test. If load determined by reference pressure gage and load determined by pressure gage differ by more than 10 percent, recalibrate the jack, pressure gage, and reference pressure gage. At load increments other than the maximum test load, hold the load just long enough to obtain the movement reading.

**PERFORMANCE TEST SCHEDULE**

<table>
<thead>
<tr>
<th>Load</th>
<th>Load (continued)</th>
</tr>
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<tbody>
<tr>
<td>Alignment Load (AL)</td>
<td>AL</td>
</tr>
<tr>
<td>0.25P*</td>
<td>0.25P</td>
</tr>
<tr>
<td>AL</td>
<td>0.50P</td>
</tr>
<tr>
<td>0.25P</td>
<td>0.75P</td>
</tr>
<tr>
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<td>1.00P</td>
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<td>1.50P*</td>
</tr>
<tr>
<td>0.25P</td>
<td>AL</td>
</tr>
<tr>
<td>0.50P</td>
<td>0.25P</td>
</tr>
<tr>
<td>0.75P*</td>
<td>0.50P</td>
</tr>
<tr>
<td>AL</td>
<td>0.75P</td>
</tr>
<tr>
<td>0.25P</td>
<td>1.00P</td>
</tr>
<tr>
<td>0.50P</td>
<td>1.50P</td>
</tr>
<tr>
<td>0.75P</td>
<td>2.00P* = Maximum performance test load</td>
</tr>
<tr>
<td>1.00P*</td>
<td>Reduce to lock-off load (0.80P)</td>
</tr>
</tbody>
</table>

* = Graph required, as specified herein.

AL = alignment load

P = design load

4. Record the anchor movement relative to the fixed reference point for the maximum performance test load at 0 time, 30 seconds, 1 minute, 2 minutes, 3 minutes, 5 minutes, 6 minutes, and 10 minutes. Also record at 20 minutes, 30 minutes, 50 minutes, and 60 minutes if creep criteria are not met at 10-minute interval. Re-pump the jack as necessary in order to maintain a constant load.

5. Creep Criteria are as follows:
a. Total anchor movement between the 1 and 10-minute intervals should not exceed 0.04 inch.

b. Total anchor movement between the 6 and 60-minute intervals (if required) should not exceed 0.08 inch.

6. Construct a graph showing a plot of anchor movement versus load for each load increment marked with an asterisk (*) in the performance test schedule, and a plot of the residual anchor movement at each alignment load versus the highest previously applied load. Submit graph format to the Resident Engineer prior to use.

D. Proof Test

1. Proof-test all production anchors as indicated in the following schedule. Raise the load from one increment to another immediately after recording of the tendon movement.

2. **PROOF TEST SCHEDULE**

<table>
<thead>
<tr>
<th>Load</th>
<th>Alignment Load (AL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25P</td>
<td></td>
</tr>
<tr>
<td>0.50P</td>
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</tr>
<tr>
<td>0.75P</td>
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</tr>
<tr>
<td>1.00P</td>
<td></td>
</tr>
<tr>
<td>1.20P</td>
<td></td>
</tr>
<tr>
<td>1.33P = Maximum proof test load; Evaluate creep Reduce to lock-off load (0.80P)</td>
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</tbody>
</table>

P = design load

3. After reaching the maximum proof test load of 1.33P, maintain the load for 10 minutes to evaluate creep based on the observed deflection behavior. Record measurements at 0 time, 30 seconds, 1 minute, 2 minutes, 3 minutes, 4 minutes, 5 minutes, 6 minutes, and 10 minutes. If the movement between the 1 minute and 10 minute hold is equal to or exceeds the creep criteria, maintain the load for an additional 50 minutes. Record measurements at 20 minutes, 30 minutes, 50 minutes, and 60 minutes.

4. Creep Criteria are as follows:

a. Total anchor movement between the 1 and 10-minute intervals should not exceed 0.04 inch.

b. Total anchor movement between the 6 and 60-minute intervals (if required) should not exceed 0.08 inch.

5. Measure and record the tendon movement to the nearest 0.001 inch with respect to an independent fixed reference point at the alignment load and at each increment of load. Use the pressure gage and reference pressure gage to measure the applied load, and use the load cell to monitor small changes of load during the constant load-hold period. Re-pump the jack as necessary to maintain the constant load.
6. Compare the results of the proof tests to the results of the performance tests. If any significant variation from the performance test is observed, as determined by the Resident Engineer, re-evaluate the design capacity of this and subsequent anchors.

E. Load Test Acceptance Criteria

1. Evaluate the results of each anchor test in order to determine anchor acceptability. An anchor will be acceptable provided:
   a. The total movement obtained from a performance and proof test exceeds 80 percent of the theoretical elastic elongation of the design free stressing length.
   b. The measured creep rate during the proof test load does not exceed the specified creep criteria and is a linear or decreasing creep rate, regardless of tendon length and load.

2. Reload anchors that do not meet the first acceptance criterion up to two times from alignment load to test load and repeat the calculation on these cycles. If the criterion is still not met, do not incorporate the tieback into the wall unless detensioned to prevent transfer of load to the no-load zone. Anchors that do not meet the second acceptance criterion cannot be incorporated into the wall at their design load, but may be accepted at a lesser load either determined from other production tests or additional tests. Lock off anchors that satisfy the acceptance criteria at the design lock-off load, which is 80 percent of the tieback anchor design load.

3. When a tendon fails, modify the design or installation procedures. The modifications may include, but are not limited to, installing a replacement tendon, reducing design load by increasing the number of tendons, modifying the installation methods, increasing the bond length or changing the anchor type. Submit modifications that require changes to the structure for review to the Resident Engineer.

4. Retesting of anchors will not be permitted, except that re-grouted tendons may be retested.

3.08 TOLERANCES

A. Deviation of anchor projection angle shall be not more than 2 degrees vertically and horizontally.

B. Locate the exposed end of the tieback within 6 inches of the location shown on the Contract Drawings of approved Working Drawings.

C. Anchor clearance to existing utilities or foundations shall be not less than 3 feet.

3.09 TIEBACK DE-TENSIONING

A. De-tension temporary tiebacks in sequence with completion of permanent structure or backfill as follows:

   1. Where permanent structure is to be built in direct contact with excavation support system, de-tension tiebacks after floor or walls above have attained design strength and after obtaining approval from Resident Engineer. Leave openings in walls as necessary to provide access to tieback for de-tensioning.
2. Where backfill is placed in direct contact with excavation support system, de-tension tiebacks after compacted backfill is placed against piles to within no more than 2 feet below center of tieback elevation.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the Tunnel Boring Machine (TBM), twin tunnel excavation using TBMs, final lining consisting of precast concrete segments, tunnel walkway, and tunnel invert.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 12 19 Contract Interface.
2. Section 01 35 29, Health, Safety and Emergency Response Procedure.
3. Section 01 55 00, Vehicular Access and Parking.
4. Section 01 57 24 Temporary Site Water Discharge.
5. Section 01 71 23, Field Engineering.
6. Section 01 74 00, Cleaning and Waste Management.
7. Section 01 74 01, Excavation Spoils and Muck Disposal.
8. Section 03 30 00, Cast-in-Place Concrete.
9. Section 05 52 14, Metal Handrails.
10. Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
11. Section 31 09 13.50, Tunnel Instrumentation and Monitoring.
12. Section 31 23 19, Dewatering.
15. Section 31 71 26, Tunnel Rescue Teams.
17. Section 31 74 16, Precast Concrete Tunnel Lining.

1.02 REFERENCES

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

1. American Petroleum Institute (API)
1.03 DEFINITIONS

A. **Mechanical Abrasion**: Detrimental wear of TBM and plant components from excavation and muck handling processes.

B. **Action Level(s)**: As defined in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

C. **Active Face Support**: Application of the Required Support Pressure to counteract earth pressure and hydrostatic head at the tunnel face. During TBM advance and stoppage the Active Face Support is applied to the tunnel face by a pressurized support medium like earth paste (EPB TBM) or bentonite slurry (Slurry TBM).

D. **Breathing Air**: Compressed air specially filtered and cooled and suitable for human consumption and supplied to support workers in the airlocks or within the Excavation Chamber while working or decompressing.

E. **Blow-Out**: Uncontrolled over pressurization within the Excavation Chamber that negatively impacts the ground surface, a water body, utility or other void space as a result of the pressurized air fracturing the ground or flowing rapidly through discontinuities, voids, or permeable zones in the ground.

F. **Boulder Stop**: A stoppage of the tunnel advance with worker entry into the Excavation Chamber to break and remove boulder(s).
G. Cutting Tools: Disc cutters, picks, drag tools, scrapers, and ripper tools mounted in the cutterhead for loosening, cutting, dislodging, and fracturing of materials indicated in the Contract Documents.

H. Conditioners: Bentonite, foam, polymers and other materials added to the excavated materials (cuttings) to modify them. Conditioners are required to mix with the excavated material to form an earth paste in the Excavation Chamber, and to reduce the abrasive nature of the materials indicated in the Contract Documents.

I. DTA: Design Tunnel Axis determined by the Contractor in order to comply with tunnel elevation and grade indicated in the Contract Documents.

J. Earth Pressure Balance (EPB) TBM:
   1. A fully-shielded TBM with an Active Face Support system.
   2. Required Support Pressure is applied to the tunnel face by a highly viscous earth paste formed by the excavated material mixed with conditioners.
   3. Earth paste is mixed within the tool gap and Excavation Chamber and pressurized by controlling the flow of material into the Excavation Chamber and out of the screw conveyor.
   4. The rate of advance is governed mostly by the cutting efficiency of the tools and the cutterhead rotation speed combined with the flow of material through the Excavation Chamber and out of the screw conveyor.

K. Excavation Chamber: The enclosed space directly to the rear of the cutterhead and ahead of the main bulkhead for the EPB TBM and ahead of the buffer wall in the Slurry TBM.

L. Face Stability Assessment: Evaluation of the stability of the tunnel face carried out prior to personnel entry for inspection and maintenance in the Excavation Chamber for the purpose of confirming or reducing or dispensing with the calculated air pressure, or recommending abandonment of the entry.

M. Factory Tests: Tests performed on equipment that certifies the equipment is in compliance with this Section in addition to the manufacturers’ specified requirements.

N. Foam Expansion Ratio (FER): Ratio between the volume of the foam and the volume of foaming solution used.

O. Foam Injection Ratio (FIR): Ratio between the volume of foam injected at atmospheric pressure and the volume of the ground in place.

P. Ground Conditioning System (GCS): The GCS is a system which permits the metered delivery of soil conditioners into the tool gap, Excavation Chamber, and screw conveyor of the TBM.

Q. Groundwater Seepage: Defined in Section 31 23 19, Dewatering.

R. Hyperbaric Intervention: TBM maintenance or inspection work carried out in the Excavation Chamber under higher than atmospheric conditions.

S. Inspection Stop: A regular stoppage of the tunnel advance either with or without worker entry into the Excavation Chamber to visually inspect condition of cutting tools, cutterhead, and other components.
T. Lost Ground: Loss or removal of material in excess of the volume excavated by the cutterhead periphery, including ground that runs, flows, pipes with groundwater inflows, squeezes, and ravels creating voids, or softened or loosened ground outside of the tunnel. Lost Ground also includes volume change associated with stress change and convergence.

U. Maintenance Stop: A stoppage of the tunnel advance with worker entry into the Excavation Chamber to repair, replace, and change cutting tools and maintain cutterhead and other components.

V. Muck: Excavated material consisting of a mixture of soil cuttings and water removed from the tunnel. Muck may include conditioner, bentonite, polymer, fragments of wood, cobbles, and boulders.

W. Open Mode Condition: A condition where the applied face support pressure is below the Required Support Pressure, when partial or no Active Face Support is applied, or during compressed air use in the Excavation Chamber for any reason.

X. Required Support Pressure: The pressure at the face that is required to fully counterbalance the hydrostatic head and earth pressure, supplemented by safety factors and operation tolerances, to prevent Lost Ground, and excess groundwater and soil inflow into the Excavation Chamber.

Y. Steering Gap: Annular space between the extrados of the shield and the overcut profile created by the cutterhead mounted over cutting tools.

Z. Slurry TBM:
   1. A fully-shielded TBM with an Active Face Support system.
   2. Required Support Pressure is applied to the tunnel face through a bentonite-water or bentonite-water-polymer slurry mixed with the excavated soils.
   3. Excavated soils are removed from the Excavation Chamber and transported out of the tunnel as suspended solids in the bentonite slurry.
   4. Compressed Air Cushion: A system which regulates the support pressure and minimizes pressure variations due to a difference between slurry inflow and outflow volumes into and out of the Excavation Chamber.

AA. Tail Void: Space between the extrados of the precast concrete segments and the surrounding soil behind the tail shield formed by overcut of the TBM cutterhead, thickness of the TBM shield, and clearance between the intrados of the shield and the extrados of the segments.

BB. Tunnel Boring Machine (TBM): A shield with excavation, ground control, steering, lining assembly and propulsion equipment, including trailing gear and support equipment required for performing tunnel excavation. A general term comprising the class of tunneling machines which is fully shielded, utilizes a full-diameter rotating cutterhead equipped with cutting tools, advances using propulsion cylinders that thrust against an initial tunnel lining erected as a ring of segments within the shield tail.

CC. Tunnel Launch: Exit of the TBM from an excavation through an eye that is cut or formed within the wall of the excavation ground support system

DD. Tunnel Reception: Entry of the TBM into an excavation through an eye that is cut or formed within the wall of the excavation ground support system
EE. Working Air: Compressed air used in the tunnel for anything other than Breathing Air.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Qualifications: for requirements see 1.05 this Section.

C. Tunnel Boring Machine (TBM): Detailed description of the proposed TBM to be used including preliminary drawings and plans within 90 calendar days of Notice to Proceed (NTP).

D. Tunnel System Plans:

1. Tunneling Excavation Plan: One integrated and structured file that presents an organized collection of data, shop drawings, plans, and method statements for the tunneling equipment and the tunneling process describing in detail and which incorporates sections for the specified aspects of the tunneling work. Submit draft version within 90 calendar days and a fully detailed Tunneling Excavation Plan within 270 Days of NTP. For completeness, include or cross-reference pertinent related components as specified in the Related Sections. Cover the following components in the Tunneling Excavation Plan:

   a. Tunneling Methods: Detailed description of the tunneling method including shop drawings of TBM to be used, method statements and drawings of the TBM operation and the tunneling process, in addition to the TBM Factory Test report.

   b. Tunnel Systems and Plant: Detailed method statements and drawings including, but not limited to, systems and plant arrangement and operation.

   c. Preparation Plan: Detailed description and drawings of Tunnel Launch and Reception including, but not limited to, seals and supplemental supports and all installations required for the TBM launching and receiving operations.

   d. Proposed Hold Points: Including but not limited to Tunnel Launches at both Roosevelt Station and re-launch from Brooklyn Station, under-passing of the Ravenna Boulevard sanitary sewer, 15th Ave NE, prior to commencing tunneling operations beneath the University of Washington campus and Tunnel Receptions at University of Washington Station for each tunnel drive.

   e. Working Plans including detailed method statements on the tunneling operations in the geologic conditions described in the Contract Documents including, but not limited to:

      1) Assembly, and disassembly operations.
      2) TBM launching and receiving operations.
      3) Tunnel excavation with face support application to maintain face stability.
      4) TBM guidance.
      5) Precast segmental lining erection.
6) Tail void grouting.
7) Compressed air operations including prevention of blow-outs.
8) Working in the Excavation Chamber including visual cutterhead inspection.
9) Refilling of the Excavation Chamber after inspection.
10) TBM maintenance.
11) Tunnel system monitoring.
12) Tunnel excavation under the University of Washington campus.
13) Tunnel excavation beneath the Ravenna Boulevard sanitary sewer for each of the running tunnels.

f. Provide a detailed description of the means and methods necessary to meet the specified requirements:

1) Tunnel launch at Roosevelt Station and re-launch at Brooklyn Station to keep ground and structure movements at or below Action Levels.
2) Ring erection and clearances for the indicated tunnel geometry
3) Prevention of blow-out during compressed air inspection and maintenance.
4) Work in the Excavation Chamber including cutterhead inspection and maintenance.
5) Soil conditioning, based on parameters identified by testing performed under paragraph 3.01 A. 3.
6) Keeping ground and structure movements at or below Action Levels.
7) Measures for protection of adjacent property.
8) Ventilation.
9) Air Quality monitoring.
10) TBM fire suppression.

g. Daily meetings to explain work to be done with tunnel crews prior to each shift.

h. Spare parts list recommended by the Manufacturer, the storage location and conditions.

2. Training Plan: Develop a comprehensive plan for orientation and training of all personnel based on all the documents within the Tunneling Excavation Plan.

3. Tunnel Safety Plan:
a. Provide detailed descriptions of the health and safety elements of tunneling including a Tunnel Safety Plan that meets the specified health and safety requirements indicated.

b. Include drawings and method statements for health and safety equipment installations including those required for air quality monitoring, fire protection, gas detection, and certifications from manufacturers that equipment meets applicable regulatory requirements.

c. Ensure compliance with all local, state and federal regulations including CFR 1926

4. Tunneling Quality Plan:

a. Include all required certifications and qualification documents including a detailed plan of the site organization and responsibilities of all planned personnel.

b. Field Quality Control: Details of TBM data acquisition and monitoring including type of data, muck control and handling systems, ground movement monitoring, reporting, and documentation.

c. Product Quality Control: Product information, certifications, and details of any probing and testing program.

d. Remedial Plan: Detailed description of remedial plans including:

1) Tunneling modifications if excessive Lost Ground occurs including plans to fill any subsurface voids or subsidence.

2) Corrective actions to be utilized for each Action Level associated with settlement and groundwater monitoring.

3) Plans for protection of adjacent facilities and property if excessive Lost Ground occurs or ground movements exceed Action Levels.

4) Plans for sealing of groundwater inflows if Tunnel Launch seal, Tunnel Reception seal, TBM seals and/or tunnel lining leakage result in flow rates that exceed limits allowed or cause detrimental Lost Ground.

5) Plan for correcting TBM alignment deviation.

6) Plans for repair of unacceptable segment off-sets, damage or segment spalling.

5. Compressed Air Work Plan:

a. Prepared by the Hyperbaric Consultant.

b. Requirements for compressed air work below 3.5 bar.

c. Include plant and equipment for the supply and use of compressed air, oxygen decompression, including but not limited to generator, stand-by equipment, air flow system control, air locks, medical locks, lighting, decompression chamber, and ventilation.
d. Include details of supervision, personnel entry, decompression, safety, and emergency procedures specific to work in compressed air.

e. Coordinate with Section 01 35 29, Health, Safety, Security and Emergency Response Procedures.

6. University of Washington Interface

a. Coordinate with Sound Transit and King County Metro for access to the University of Washington Station.

b. Northbound and Southbound running tunnels: Prepare the TBM’s for complete disassembly from within the tunnel at the tunnel station position indicated in the Contract Documents. Leave the shield of the TBM’s in place as temporary support, and complete the tunnel lining as indicated.

E. Certification of Compliance: at least 60 calendar days prior to TBM launch for:

1. Conditioners.
2. Lubricants, oils, greases, etc.
3. Fire resistant hydraulic oil.
4. Class 1 Division 2 for TBM and trailing gear.
5. TBM Fire Suppression Systems.
6. Conveyor belts in accordance with NFPA
8. Main bearing and seal manufacturer.
9. Lifting and hoisting equipment.
10. Air locks and compressed air equipment.
11. From the TBM manufacturer that the new-TBM and associated components meet all the requirements indicated in the Contract Documents.

F. Test Reports: within one week of testing for:

1. TBM Factory Tests.
2. TBM site tests and re-calibration.
4. Slurry preliminary suitability tests.
5. Tail void grouting preliminary suitability tests (see Section 31 73 23, Tail Void Grouting).

G. Calculations: at least 60 calendar days prior to TBM launch for:

1. Ventilation system flow and capacity.
2. Face support calculations, including Required Support Pressure, based on piezometric level information presented in the Contract Documents.

3. Programmed unit weight of excavated material.

H. Daily submission of:
   1. Shift reports.
   2. Ring Reports.
   3. Settlement monitoring and instrumentation reports: Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
   4. TBM data logger records.
   5. Tail Void grouting reports.
   6. Muck samples and sampling report.

I. Weekly submission of:
   1. Electrical inspection records.
   2. Ventilation performance records.
   3. Muck haulage records.
   4. Testing of Tail Void grout samples taken during production grouting.
   5. Records of water discharge from muck storage area: Section 01 57 24, Temporary Site Water Discharge.

J. Monthly Submission of:

K. Event submission within 24 hours:
   1. Hyperbaric Interventions
   2. Inspection Stop documentation report.
   3. Cutterhead maintenance report.
   4. TBM maintenance report.
   5. Lost Ground reports.
   6. Reports of combustible or toxic gas.
   7. Documentation of actual excavated weights exceeding theoretical by more than ten percent.

L. Contingency Plans: detailed description of the actions and procedures to be taken for the following events at least 60 calendar days prior to TBM launch.
1. Lost Ground.
2. TBM outside DTA tolerance window.
3. Lost Ground under Ravenna Boulevard sanitary sewer and under the Neptune Theatre during TBM retrieval into the Brooklyn Station box and under the University Manor Apartments during TBM launch out of the Brooklyn Station box.
4. Inundation events.
5. Power loss.
7. Fire.
8. Injury during a Hyperbaric Intervention.
10. Gas alarm activation and TBM shutdown.

M. Muck Handling Plan:

1. For slurry TBM:
   a. Slurry separation plant design and system layout showing the type and number of each process component used. Include details of system capabilities to deal with clay clogging potential and slurry separation of clay soils.
   b. Total plant slurry process rate.
   c. Process flow and tonnage capacity for each system component.
   d. Pipe sizing and piping network plan.
   e. Slurry pumping design including velocity requirements for soil transport.
   f. Slurry materials mix design and spoil loading capacity.
   g. Materials handling for slurry recirculation and waste disposal.
   h. Separated tunnel spoil solids containment and handling method.

2. For EPB TBM:
   a. Narrative and drawings describing in-tunnel muck handling facilities including rail and rolling stock or conveyor details.
   b. Surface muck handling and storage including supernatant or other water discharge from the muck.

N. Tunneling Pre-Submittal Meeting Agenda and Minutes:

1. Agenda to include general information regarding:
   a. Tunneling methods, including equipment layout, TBM operation, and tunneling process.
b. Tunneling operations.
c. Means and methods.
d. Orientation and training.
e. Tunneling health and safety: Section 01 35 29, Health, Safety, and Emergency Response Procedures.
f. Access for maintenance and inspection under varying pressures.
g. TBM data monitoring.
h. Contingency plans.

2. Meeting to be held at least 30 calendar days prior to first TBM launch.

O. TBM inspection and maintenance procedures within the Brooklyn Station box excavation.

P. TBM removal and in-tunnel disassembly at University of Washington Station:
   1. Submit TBM and related equipment removal plan.

Q. Muck Sample Reporting Plan:
   1. Include:
      a. Sampling method
      b. References of third-party testing agency
      c. Proposed tests to be carried out.
      d. Sample test reports

1.05 QUALITY ASSURANCE

A. Qualifications:
   1. Site Superintendent: Have a minimum of five years total on-the-job tunnel supervision experience with:
      a. The type of TBM proposed for use.
      b. Tunneling of similar size.
      c. Segmental Lining consisting of bolted, gasketed, precast concrete segments.
      d. Tunnels driven through ground conditions similar to those indicated in the Contract Documents.
   2. Shift Foremen: Have a minimum of three years total on-the-job tunnel crew supervision experience with EPB TBMs or Slurry TBMs of similar size, with initial tunnel lining by bolted gasketed precast concrete segments, and in similar ground conditions.
   3. TBM operators: Have experience with at least two projects operating and guiding the type of machine approved in the Bid Evaluation (EPB TBM or Slurry TBM) of
similar size, with initial tunnel lining by bolted gasketed precast concrete segments, and in similar ground conditions.

4. TBM Manufacturers Representative: A senior technician with a minimum of ten years experience training contractor personnel in all aspects of TBM operation and maintenance.

5. Hyperbaric Consultant: Experience on at least two projects providing hyperbaric consulting and management services with personnel entry into a TBM Excavation Chamber at pressures up to 3.5 bar.

1.06 SITE CONDITIONS

A. Geological and hydro-geological conditions are presented in the Geotechnical Baseline Report (GBR) and Geotechnical Data Report (GDR). Baseline ground and groundwater conditions are established in the GBR. Boring logs, laboratory testing results and geotechnical data are provided in the GDR

B. Review the Contract Drawings and area available for TBM launch including the time and area constraints governing the work at the Roosevelt Station Site and for the TBM re-launch at the Brooklyn Station Site.

C. Review the Contract Drawings and area available for TBM removal at the University of Washington Station site.

D. Hazardous Gas:

1. Tunnel Classification: Due to expected organic soil deposits and methane gas, the tunnel is classified as potentially gassy.

2. Hazardous gas control measures specified herein are supplemental to OSHA requirements. Consider measures specified herein minimum additional measures.

3. Assume sole responsibility for development and implementation of measures to control gas emissions and for proposing alternative or more stringent means, if necessary, to accomplish the objectives of these provisions.

4. Additional measures are indicated in Article 2.02 E. 20. d.

1.07 TRAINING

A. Ensure foremen, shift engineers, TBM operators, and technicians are trained, qualified, and familiar with TBM, tunnel system and plant, and trained using the written procedures and work plans contained in the Tunneling Excavation Plan adhering to the following minimum training schedule:

1. Initial training prior to TBM launch.

2. Start-up training.

3. Periodic re-training as required for changes to staff, equipment or conditions.

4. Specialized preparation and training for compressed air workers.

B. At least one member of each tunnel crew working underground shall hold a valid first-aid certificate.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Precast Concrete Tunnel Lining: Section 31 74 16, Precast Concrete Tunnel Lining.

B. Slurry or EPB Soil Conditioners: Inert or biodegradable, accompanied by the manufacturers’ certificate of compliance.

C. Tail Void Grout: Section 31 73 23, Tail Void Grouting.

D. Oil and Grease: Flame resistant and biodegradable and accompanied by the manufacturers’ certificate of compliance, compatible with segment gasket material and in accordance with TBM manufacturer recommendations.

2.02 EQUIPMENT

A. General:

1. TBM(s): Capable of excavating the N120 twin running tunnels and erecting the bolted and gasketed precast concrete segmental lining indicated while maintaining face stability and minimizing ground settlements in the geological conditions described in the Contract Documents and in accordance with the schedule requirements.

2. Fulfill all requirements listed in Article 2.02, herein, prior to work commencement of work in accordance with Article 3.01, herein.

B. Ensure that TBM(s), tunnel systems and plant meet all OSHA and Washington Industrial Safety and Health Administration (WISHA) regulatory requirements.

C. Fully assemble and Factory Test TBM(s) and trailing gear prior to shipment to Site. Upon reassembly at Site, re-test the TBM and re-calibrate all components.

D. Factory Test the Ground Conditioning System (GCS) and adjust so that all functions are within the manufacturers’ recommendations prior to the TBM delivery.

E. Tunnel Boring Machine (TBM):

1. General:

   a. Provide one or two new Slurry or EPB TBMs.

   b. Provide ability for drilling equipment to be mounted in the TBMs, and provide drilling ports equipped with valves incorporated into the TBM shield to permit drill casings to be sleeved through glands into ground when drilling ahead of the TBM.

   c. All items and requirements listed for the TBMs in Article 2.02E, herein, are required for the TBMs to be utilized on the Contract

2. Cutterhead and Tools:

   a. Design and configure the cutterheads with wear protection to enable efficient excavation of the ground indicated in the Contract Documents.
1) Provide sufficient cutting tool spacing to permit efficient excavation of the material at the tunnel face with sufficient tool gap and penetration for both disc and ripper type cutters.

2) Incorporate adjustable gauge cutters.

3) Design the cutterhead to permit the use of both disc cutters and ripper type cutters which can be replaced from the Excavation Chamber (back loading) and are interchangeable with each other.

4) Wear indicators on tools located in the gauge position with status indication at the TBM operator position.

5) Ensure the cutterhead limits the size of boulders which can be admitted to the screw conveyor on an EPB machine or the stone crusher on a Slurry TBM.

6) Provide a minimum of three ports on the cutterhead to permit the injection of ground conditioning agents.

3. Excavation Chamber:
   a. Provide mixing arms on the rear of the cutterhead and on the Excavation Chamber bulkhead.
   b. Provide a minimum of six ports in the Excavation Chamber bulkhead.

4. Cutterhead Drive System and Main Bearing:
   a. Adequate torque and power to the cutterhead so that the machine is not torque limited while operating under any of the ground conditions indicated in the Contract Documents.
   b. A reversible, variable-speed cutterhead drive system with two speed ranges capable of starting at maximum torque.
   c. Provide certification from the main bearing manufacturer that the bearing is suitable for the speeds and loads anticipated based on the geotechnical conditions indicated in the Contract Documents as calculated by the TBM manufacturer and that the main bearing has a minimum bearing life of two times the anticipated operational hours.
   d. Oil lubricated main bearing with pumping and filtration circuits equipped with accessible sampling points.
   e. Ensure main bearing is new and replaceable from within the tunnel.

5. Face Support System:
   a. Design the TBM to allow operator controlled application of Active Face Support at all times:
      1) EPB TBM:
         a) During TBM advance or extended stoppage by earth paste.
b) Provide six earth pressure sensors within the Excavation Chamber: two sensors near the crown, tunnel spring line and invert replaceable from the atmospheric side of the main bulkhead at any time.

2) Slurry TBM:
   a) During TBM advance or extended stoppage by slurry.
   b) Four pressure sensors capable of measuring air and slurry pressure at crown level.
      i) Two sensors to be installed at the buffer wall within the Excavation Chamber.
      ii) Two sensors to be installed at the bulkhead replaceable from the atmospheric side of the main bulkhead under the design operating conditions.
   c) Two additional redundant liquid level sensors at the bulkhead that utilize different sensor technology than the other four sensors. Verify sensor accuracy is consistent with required face pressure control tolerances.
   d) Compressed air cushion between the buffer wall and main bulkhead for automatic regulation of the face support pressure.

3) EPB and Slurry TBM:
   a) During inspection, maintenance, and boulder stops, by a continuous bentonite membrane and compressed air within the Excavation Chamber with supplementary support, if necessary.
   b) Measure support pressure with calibrated, abrasion resistant pressure sensors.
   c) Pressure sensor accuracy of $\pm$1 psi and a range of 0 to 100 psi.

6. Seals:
   a. Incorporate the following into the Main Drive sealing system:
      1) New main bearing seals designed to handle maximum Active Face Support pressure with minimum dynamic safety factor of 1.5.
      2) Ensure the two forward main bearing seals are replaceable from within the Excavation Chamber without necessitating cutterhead removal.
   b. Incorporate the following into the articulation joint seals:
      1) Designed for maximum Active Face Support pressure, and grouting pressure with a minimum safety factor of 1.25.
2) Designed to allow adjustment and replacement of the seals from within the shield.

3) An inflatable safety seal deployable when work is carried out on the seals or in an emergency where leakage cannot be controlled by any other means.

c. Incorporate the following into the shield tail seal:

1) A switchable automatic with manual override grease fed triple wire brush sealing system capable of sealing hydrostatic, earth, and tail void grouting pressures and compatible with Section 31 74 16, Precast Concrete Tunnel Lining and Section 31 73 23, Tail Void Grouting.

2) Spring steel sealing plates designed to prevent the steering gap from grout ingress.

3) A minimum of three rows of wire brush seals with at least two rows replaceable from within the tunnel.

4) An inflatable safety seal deployable when work is carried out on the brush seals or in an emergency where leakage cannot be controlled by any other means.

7. Propulsion and Steering System:

a. Propulsion system that can advance the TBM under the combined maximum loads of tool, earth and hydrostatic pressure, shield friction, and trailing gear drag with a minimum safety factor of 1.5.

b. Propulsion cylinder extensometers at four positions separated by 90 degrees.

c. Ensure that maximum thrust contact pressure at any point and at any time on the precast segmental lining does not exceed 50 percent of the maximum permissible jacking load in the precast segmental lining design.

d. Propulsion cylinder shoes or partial jacking rings as required to distribute thrust loads across the leading edge of the precast segment ring without developing eccentric loading on the segment ring for which the segments were not designed.

e. The propulsion cylinders: Concentric with segmental ring centerline.

8. Shield Articulation:

a. A selectable active/passive articulation joint between the main shield and the tail shield equipped with hydraulic cylinders to permit the TBM to follow the DTA.

b. Sufficient injection ports around the circumference of the articulation joints such that cleaning or other operations can be easily carried out.

c. Extensometers at four positions on both the active and passive cylinders.

d. Sufficient extension/retraction to permit disengagement with an obstacle.
9. Operator Position:
   a. An ergonomic operator position which permits access to all controls, gauges and monitoring devices to permit safe operation of the TBM.
   b. Displays for PLC input/output and continuous guidance system monitoring.

10. Resident Engineer Position:
    a. A position near the operator’s console for the Resident Engineer permitting a view of grouting and ring building activities, including access to the TBM gauges and monitoring devices.
    b. A dedicated computer with monitor and printer equipped with appropriate software to view historic and real time TBM data from the Data Monitoring System indicated in 2.02 E. 18.

11. Erector system:
    a. Assemble segments by an erector mechanism into rings under protection of the tail shield in the orientation and to the tolerance specified in Section 31 74 16, Precast Concrete Tunnel Lining, without causing damage to the precast segments or gaskets.
    b. Use an erector system that is compatible with the TBM and precast segmental lining and meet the requirements specified in Section 31 74 16, Precast Concrete Tunnel Lining.

1) Design the lifting and gripping mechanism (mechanical or vacuum) to handle all loads with an adequate factor of safety in the axial, radial, and circumferential directions, and in the three articulation angles corresponding to the six degrees of freedom.

2) Provide sufficient rigidity and longitudinal travel to permit installation or removal of a segmental ring located on the wire brush seals.

3) Incorporate safety devices to ensure segments cannot be released during handling. In the event of a loss of power, ensure the erector permits safe lowering of the segments.

4) The segment feederSupply the erector with segments at the correct orientation and be capable of reverse operation for the removal of damaged or incorrect segments.

5) Ensure segment erector arm has sufficient capacity to adequately compress the precast segments longitudinal joint gaskets for correct installation.

12. Grouting System:
    a. TBM Tail Void grouting system: Capable of continuous grouting during TBM advance through lines integrated into the tail shield in accordance with Section 31 73 23, Tail Void Grouting.

1) Install six twinned (one primary and one spare) grout injection lines around the circumference of the shield, and design for
continuous grout flow while maintaining filling and pressure with the maximum advance rate of the TBM.

2) Equip each grout line with a pressure sensor accurate to +0.1 bar and manual stop valve at the tail shield connection.

3) Provide a scale device and/or ultrasonic sensor for measuring weight and/or volume of grout injected and display at Operator’s position and to data logger.

b. Computer controlled grout pumps: Provide pressure and volume measurement for each of the lines continuously to the TBM display and data logging system.

c. Dedicate one pump to each grout injection line.

d. Minimum of two injection lines must be used at all times.

e. Equip pumps with water/bentonite connection to facilitate flushing.

f. Drilling equipment and associated staging to enable recovery of Tail Void grout samples and proof grouting at any position around the ring in accordance with Section 31 73 23, Tail Void Grouting.

13. Proof Grout Equipment:

a. General: Provide proof grouting pumping equipment and hoses to ensure continuous circulation of grout within the system.

14. Muck Handling System:

a. Design the muck handling components for abrasion resistance and durability for the indicated ground conditions.

b. EPB TBM:

1) Size and configure the GCS as required to form a homogeneous earth paste suitable for control of Required Support Pressure for all ground conditions indicated in the Contract Documents. Use a computer controlled system with interactive parameter setting at the operator position.

2) Provide a dedicated foam generator with bypass pump and flow measurement system to each outlet on the cutterhead.

3) Provide a reversible double screw with primary and secondary sections which are equipped with dedicated drives and separated with a guillotine gate. Provide the capability for the automatic charging and releasing of excavated material from the secondary screw which will permit the controlled excavation of non-cohesive materials under groundwater pressure indicated.

   a) As a substitute for the secondary screw a positive displacement device or similar equipment which permits the controlled release of pressurized material from the primary screw and is equipped with a positive closure device may be used.
4) Locate the screw conveyor inlet at the bottom of the Excavation Chamber and equip the inlet with bulkhead doors designed to isolate the screw conveyor from the Excavation Chamber. Fit the screw conveyor sections with wear-resistant plate removable from the screw sleeves in the tunnel.

5) Fit the secondary screw outlet with a guillotine gate designed to operate and seal maximum hydrostatic and earth pressure in all soil types indicated.

6) Equip the screw conveyor sleeves with:
   a) A minimum of two pressure sensors, one located near the inlet of the primary screw and the other near the outlet of the secondary screw.
   b) Injection points along its length to permit the introduction of ground conditioners into the screw.
   c) Removable inspection hatches fitted with valves to permit access to mechanical linkages and for the removal of blockages which may occur within the screw.
   d) Provide equipment required to refill the Excavation Chamber.
   e) Accumulator with automatic valve which will close the screw guillotine in the event of a power failure.

c. Slurry TBM:

1) Minimum of eight slurry injection nozzles, four within Excavation Chamber and four in the stone crusher/discharge inlet area within the Excavation Chamber.

2) Abrasion resistant closed circuit mucking system capable of discharging solids through a slurry discharge line and discharge pumps that are sized for the muck volume and advance rate anticipated. Include:
   a) Bypass line and associated valves.
   b) Hydraulic accumulators to ensure closure of all bulkhead flanges in case of power loss.

3) Equipment to measure weight of the excavated material at the separation plant:
   a) Flow and density meters in the supply and discharge slurry lines.
   b) Locate density meters in the return lines in the station excavation and fitted to the vertical pipes carrying the slurry up to the separation plant.
   c) Bentonite slurry recharge flow meter.
d) An operational status of the slurry plant including key pumps and level indicators and weight of discharged muck.

15. Muck Control System:

a. Equipment to measure the amount of excavated material during advance for each segment ring.

b. Designed to assist the TBM operator by comparing the theoretical excavated material relative to propulsion cylinder stroke to the actual excavated material at a given stroke length and display these in real-time to the operators’ position.

c. EPB TBM:

1) Include twin conveyor scales connected to the TBM PLC integrated with propulsion cylinder stroke measuring units.

2) Provide direct measuring conveyor scales that provide instantaneous and total weight measurements of excavated soil to the TBM PLC which are programmed to compare weights and volumes of each successive ring.

3) If a continuous conveyor is used, provide a twin belt scale weighing system connected to the TBM PLC with values continuously displayed in the Operator’s position. Non-weighing nuclear density sensors are not acceptable substitutes for scales.

d. Slurry TBM:

1) Include flow and density meters in the supply and discharge slurry lines and TBM PLC propulsion cylinder stroke measuring units integrated together to provide volumetric and unit weight measurements for each segmental ring.

2) Density meters in the return lines located in the station box excavation and fitted to the vertical pipes carrying the slurry out of the excavation.

16. Active Face Support Pressure Control System:

a. Equip the TBM(s) with an automatic pressure compensation system for applying bentonite to the Excavation Chamber and Steering Gap in the event that the measured face pressure falls below the minimum Required Face Support pressure.

b. Provide at least one dedicated bentonite feed line to the Excavation Chamber and a minimum of six lines through the shield.

c. Record the bentonite consumed during TBM operation.

17. TBM Guidance System:

a. TBM with a computerized laser-theodolite based guidance system and related software.
b. Capable of displaying the precise position and orientation of the TBM on a continuous basis with numerical and graphical display of horizontal and vertical deviation from the DTA and direction with respect to the DTA.

c. Capable of displaying the position and orientation of the erected rings with the horizontal and vertical deviations from the DTA.

d. Capable of calculating and displaying correction curve with interactive parameter setting.

e. Monitor, record, and display:
   1) Date, time, and tunnel station continuously.
   2) Segment ring, DTA stationing values, as-driven coordinates and elevations, horizontal and vertical offsets from DTA.
   3) The number and orientation of tapered segment rings required to achieve the desired alignment and the location of the axis of each ring relative to the axis of the tail shield.
   4) Extensions of propulsion and active/passive articulation cylinders.

18. **TBM Data Monitoring and Acquisition System:**

   a. System for real-time data monitoring and acquisition, storage and display system for:
      1) Propulsion cylinder stroke at a minimum of four positions. Show pressure, average instantaneous advance rate and total thrust for all cylinders.
      2) Extensions of propulsion and active/passive articulation cylinders at a minimum of four positions, pressure and total thrust.
      3) Cutterhead rpm, direction and torque.
      4) Electric motor status and power consumption.
      5) Main bearing and main bearing sealing system oil pressure, temperature and flow.
      6) TBM Guidance System data.
      7) Face support pressure.
      8) Compressed air pressure and air flow for both working air and breathing air.
      9) Muck Control System data including instantaneous and total muck weights, actual and programmed muck weights compared to propulsion jack position.
      10) Bentonite Injection volumes from the Active Face Support Pressure Control system.
11) GCS data including water, polymer and foam solution flows and pressure, air flows and pressure, Foam Injection Ratio (FIR) and Foam Expansion Ratio (FER) for each individual line.

12) Discharge system from Excavation Chamber including stone crusher and screw conveyor rotation speed and guillotine gate position indication.

13) Bulkhead valve status for the Slurry TBM.

14) All gases included in the air quality monitoring system.

15) Pressures and volumes of shield tail grouting and tail seal grease.

b. Record data at maximum time intervals of ten seconds and display in real-time at:
   1) TBM operator’s position.
   2) The Contractor’s Site office.
   3) The Resident Engineer’s Site office.

c. Store and record data via an automated acquisition system in digital form for later use and retrieval. Supply the Resident Engineer with the data on a continuous basis.

d. Secure Internet-based access to real time data for use by the Resident Engineer in the Resident Engineer’s Site office.

e. Maintain hardware necessary for recording and real time viewing of data at the Site. In the event of downtime due to hardware within the Contractor’s control, notify the Resident Engineer of the issue, repair hardware, and restore Internet-based access to real time data within 48 hours of hardware failure. Maintain recording of data at all times.

f. Maintain redundant data logging on the TBM at all times and make this data available in the event that downtime described in Article 2.02 E 18 e. herein occurs.

19. Spare Parts:
   a. Provide spare parts inventory for the duration of TBM excavation as recommended by the TBM Manufacturer.
   b. Available on Site at all times:
      1) Guidance system and data logger system spares.
      2) Provide and maintain one complete set of each type of (disc, ripper and scraper) of cutting tools and associated mounts and seals.
   c. Available at the Site within ten days:
1) Provide one spare main bearing and associated seals, one spare screw conveyor assembly (screw, casing, associated mounts and seals).

20. Tunnel Systems and Plant:
   a. Communication Systems:
      1) Hard wired telephone communication system operable at all times. Include phones at TBM, along the tunnel alignment at intervals of 800 feet, corresponding to cross passage locations at California switches, at the station box excavation bottom, and at ground surface.
      2) Wireless communication system on locomotives linked with station box excavation bottom and TBM.
      3) Signaling system for trains entering the TBM back-up area.
   b. Compressed Air Equipment:
      1) Include all equipment required for applying face support by compressed air for worker access to the Excavation Chamber in accordance with all applicable regulations.
      2) Comply with requirements of WAC 296-36 and Section 01 35 29, Health, Safety, and Emergency Response Procedures.
      3) A compressed air lock system for minimum three persons each which permits safe access into the pressurized Excavation Chamber fitted to the pressure bulkhead of the TBM and equipped with pressure equalization valves between Excavation Chamber and airlocks.
      4) An integrated transport system for the air lock or material lock which permits the passage of materials such as excavation tools into the Excavation Chamber.
      5) Telephone within the compressed air lock and connection for telephone within Excavation Chamber.
      6) Capable of providing and maintaining compressed air pressure in the Excavation Chamber at any required level up to 3.5 bars.
      7) Capable of providing airflow capacity sufficient to maintain air pressure in the Excavation Chamber at the desired level during maximum expected air loss through the face.
      8) Equipment for oxygen decompression in both air locks.
      9) Breathing masks with independent air supply for welding within the Excavation Chamber.
     10) Utility hookups required for work under compressed air within the Excavation Chamber.
   c. Materials Handling for Working in the Excavation Chamber:
1) Appropriate materials handling equipment to permit the safe passage of excavation tools and other materials from the end of the segment feeder into the Excavation Chamber.

2) Provide attachment points for safety harnesses and lifting devices.

3) Provide steps for safe personnel access.

d. Electrical System:

1) Design the TBM and trailing gear according to Class 1 Division 2 standards for gassy locations and all other requirements set forth by OSHA or other applicable regulatory agencies.

2) The primary power distribution system with the means for limiting high-voltage fluctuations when starting up or shutting down the TBM.

3) An emergency standby generator with a capacity and configuration to automatically come on-line in the event of a power failure to operate ventilation, lighting, pumping, communications, air compressors and other systems without interruption.

4) Power interrupt: Automatically shut down power to the TBM and trailing equipment upon detection of an air quality event such as explosive or toxic gas levels exceeding the regulation limits, while maintaining power to the: ventilation, emergency lighting, dewatering pumps, and safety support systems.

e. Lighting Systems:

1) Primary lighting system for the entire length of the tunnel to NEC Class 1 Division 2 standard.

2) Additional lighting in tunnel: Sufficient for inspection of construction operations by the Resident Engineer.

3) Flashlights: Approved by MSHA as permissible.

4) The use of flame safety lamps is prohibited.

f. Water Pumping in Tunnel:

1) Pumping capacity at the Excavation Chamber and TBM as required to remove accumulations of water from construction discharges and any groundwater inflows at the heading or through shield articulations or wire brush seals.

2) Sufficient intermediate pumping stations and pumping capacity along the tunnel as required to remove water accumulations from construction discharges and any groundwater seepage and to maintain accumulated water levels below tunnel railheads.

3) Sump, pump, and discharge lines at the portal as required to remove water accumulations from construction discharges, Groundwater Seepage, and sudden water inflows.
g. Slurry TBM Feed and Discharge Lines:

1) Design slurry lines, valves, and pumps to transport the materials indicated in the Contract Documents.

2) Use intermediate pumps along the tunnel alignment sufficient to provide slurry flow rate and pressure needed for Required Support Pressure and slurry discharge for the anticipated maximum TBM advance rate and tunnel length.

3) A minimum of two abrasion resistant pressure sensors along the slurry charge (feed) line segment and two additional abrasion resistant pressure sensors along the slurry discharge line which can be replaced under operating conditions.

h. Slurry TBM Bentonite Mixing and Separation Plant:

1) Design slurry separation plant to separate bentonite slurry and the excavated soil material generated from tunneling through the indicated conditions including areas of ground improvement.

   a) Capable of handling the anticipated volume rates, types, and quantities of materials anticipated.

   b) Capable of balancing the removal of solids from suspension with the Slurry TBM advance rate.

2) Recirculate the processed slurry and provide means of reconditioning and replacing lost slurry as required by ground conditions at heading.

   a) Ability to increase slurry density to counter slurry loss and to prevent face collapses.

   b) Slurry suspension reserve with a minimum volume of 15,000 gallons for use if a sudden, high flow rate slurry loss occurs during tunneling in highly permeable soils.

i. Personnel and Materials Transportation System:

1) For the transportation of material, supplies, compressed air support equipment, persons, and injured persons with consideration of higher tunnel gradients at California switches and ramps.

2) Locomotives: Conform to the requirements of MSHA 30 CFR 36.

   a) Equipped with all-wheel fail-safe braking system.

3) Rail Cars: Equipped with all-wheel fail-safe braking system.

4) Fit all rolling stock and any trackless equipment to be used in the tunnel with a fail-safe braking system.

5) Any trackless equipment to be used in tunnel must be fitted with a parking brake capable of holding itself while fully loaded on the steepest slope to be encountered.
6) Provide derailer and/or barrier mechanisms at points along the tunnel track work.

7) Limit train speed to 10 mph.

8) Carry-out a comprehensive track work maintenance and housekeeping regime.

j. Muck Transport Conveyor System for EPB TBM:

1) Provide a continuous conveyor muck transport system integrated with the TBM including related safety equipment.

2) Where the continuous conveyor is used in a curve fit belt safety guards designed to prevent accidental straightening of the conveyor belt.

3) Do not advance the TBM more than 600 feet on either the north or south running tunnels until the continuous conveyor for the TBM has been fully installed and commissioned.

k. Ventilation System:

1) Meet all OSHA and WISHA regulatory requirements and in accordance with the NEC Class 1 Division 2 standard.

2) Fully reversible with ability to meet all performance and air quality criteria in exhaust or intake mode.

3) Make main ventilation duct of non-combustible materials.

4) Locate exhaust stacks of the ventilation system to prevent recirculation of exhaust air into the air intake shaft or station box excavation.

5) Design:

   a) Unless otherwise indicated, meet or exceed minimum requirements of OSHA.

   b) When the tunnel or other underground excavations are occupied, design the primary ventilation system to deliver fresh air to the heading at a volumetric flow rate of at least 90 feet per minute multiplied by the excavation cross section measured in square feet.

   c) Configure and operate fans to minimize recirculation of air in the TBM.

   d) Where the ventilation system in the TBM is operating in an exhaust mode, provide ventilation by a supplementary fan positioned to minimize recirculation.

   e) Provide additional equipment for ventilating confined areas of the TBM not reached by the main ventilation system, including the Excavation Chamber when occupied by personnel.
6) Ensure power to the primary ventilation system is not interrupted in the event of a gas detection system alarm.

1. Use primary ventilation and booster fans for tunnel ventilation and related electrical equipment and cables located within the tunnel or station box excavations approved for use in gassy locations.

21. Health and Safety Equipment:

a. In addition to the health and safety requirements in Section 01 35 29, Health, Safety, and Emergency Response Procedures, meet the following requirements for equipment used in tunneling:

1) Equip TBM with integrated safety systems as described in this Section and in accordance with applicable regulatory requirements for underground construction equipment.

2) All equipment: Rated for use in Class 1 Division 2 hazardous locations.

b. Minimum Fire Protection Requirements:

1) Manually operated fire suppression systems within TBM and along trailing gear for all electro-hydraulic installations, heat sources, and the TBM transformer.

2) A clear emergency escape way from the TBM along the trailing gear.

3) Fire suppression system on all haulage equipment.

4) Fire extinguishers at the TBM control panel, in the air locks, and at 25 feet intervals along the trailing gear.

5) A water curtain at the rear end of the trailing gear.

c. Equip all personnel entering the tunnel with oxygen re-breather type self rescuers.

d. Air Quality Monitoring:

1) An air quality monitoring and alarm system to monitor gas concentrations including but not limited to, carbon monoxide, nitrogen oxides, hydrogen sulfide, oxygen, methane and airborne particulate concentrations in the tunnel atmosphere.

2) Continuous air quality monitoring on the TBM with readings captured by the TBM Data Monitoring and Acquisition System and recorded by data logger at intervals of 10 seconds or less.

3) Design the alarm system to de-energize the TBM, at no more than 20 percent of LEL for methane or any other combustible gas.

4) Position sensors at locations that provide the most effective measurement of combustible and toxic gases. Do not place sensors within a fresh air stream.
5) Use handheld multi-gas detectors including, but not limited to, carbon monoxide, hydrogen sulfide, oxygen and methane by properly trained personnel when entering the chamber under free air conditions.

PART 3 - EXECUTION

3.01 PREPARATION

A. TBM Testing:

1. Fully assemble and Factory Test TBM(s) and trailing gear prior to shipment to Site. Upon reassembly at Site, re-test the TBM and re-calibrate all components.

2. Provide travel, accommodations, and meals for two persons from the Resident Engineer team to attend Factory Tests.

3. Factory Test the Ground Conditioning System (GCS) and adjust so that all functions are within the manufacturers’ recommendations prior to the TBM delivery.

B. Before TBM launching and start-up operations, the following preparation and installations are required:

1. Install and baseline geotechnical instrumentation: Before commencement of tunnel launch, ensure that all specified geotechnical instrumentation has been installed, is functional, has been base-lined and is being monitored as specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

2. Provide an on-site TBM manufacturer’s representative to train the Contractor’s personnel in the operation and maintenance during start-up and the initial 1000 feet of tunnel advance.

3. Commission compressed air plant and related services required to supply each TBM.

4. Prior to launch and start-up operation of an EPB TBM determine the required soil conditioner properties in order that workable mixtures of earth paste and soil conditioners for the anticipated soil types may be determined.
   a. Carry out systematic testing of the different soil types to determine the range of soil conditioning parameters, including foam expansion ratios (FER), foam injection ratios (FIR), types and concentrations of foam agents, polymers or other materials, in order to be ready to apply when required.
   b. Carry out calibration of the GCS in order to ensure consistent conditioner application.

5. Prior to launch and start-up of the Slurry TBM, determine and check the properties of the slurry to be utilized.

6. Confirm that the Field Quality Control section, specified in Section 31 32 13.36, Jet Grouting Soil Stabilization, has been completed.

7. Tunnel Rescue Teams in place per Section 31 71 26, Tunnel Rescue Teams.
8. TBM Data Monitoring and Acquisition System is tested and fully operational.

9. All site water discharge systems for Section 01 57 24, Temporary Site Water Discharge including sump, pump, and discharge lines are tested and ready for operations that meet discharge requirements indicated.

10. Complete all necessary training for workers required to perform work under compressed air.

11. Verify correct operation of all safety equipment and material handling equipment including operation of equipment for the supply of materials and equipment to the excavation chamber to the satisfaction of the Resident Engineer.

12. Tunnel System Plans have and acceptable disposition.

C. Launching from Roosevelt Station and re-launch from Brooklyn Station:

1. Provide all installations in the station box for TBM launching, start-up and tunnel operation, including installation of supplementary supports or bracing required for structural support, thrust abutment, and launch cradle.

2. Provide launch sealing structure for TBM launch which seals the gap between the headwall, soil and TBM and the gap between head wall, soil and the extrados of the segmental lining.

3. Provide anti-roll devices on the TBM shield during the launch operation.

4. Complete the following before advancing the TBM cutterhead beyond the Ground Improvement zone or ground support:
   a. Install at least one complete ring of segments and grout the tail void between the segments and portal support wall to form a watertight seal.
   b. Fill Excavation Chamber with earth paste or slurry and apply Required Support Pressure.

D. Active Face Support Pressure Calculations:

1. Provide support pressure calculations for entire tunnel drive for advancing, non advancing, and inspection, maintenance, and boulder stoppage based on anticipated ground and groundwater conditions. Include with calculations:
   a. Description of calculation method used and references used.
   b. A table and a tunnel profile showing the Required Support Pressures with depth across tunnel face for each tunnel advance along the tunnel alignment. These calculations may be reduced to reaches no longer than the interval between boreholes as indicated in the Contract Documents. Likewise, integrate the tail void grouting pressures and volume related to the face support pressures along the alignment in accordance with Section 31 73 23, Tail Void Grouting.
   c. Include groundwater pressure, earth pressure, and tolerance component in calculating the Required Support Pressure.
   d. Detail descriptions of factor of safety used for both groundwater and earth pressures.
e. Include a tolerance of 0.3 bar for face support by earth paste (EPB TBM), 0.1 bar for face support by slurry (Slurry TBM), and 0.05 bar for face support by compressed air.

2. Check resulting Required Support Pressures for safety against air blow-out and adjust air pressure if necessary to provide a minimum factor of safety of 1.2.

E. Pre-Tunneling Meeting:

1. At least 30 calendar days prior to TBM launch, conduct a meeting with the Resident Engineer to discuss aspects of the tunneling work relating to the monitoring, data acquisition and reporting, communications, testing plan, safety, quality procedures, and tunnel rescue teams.

2. Prior to the excavation beneath each of the Ravenna Boulevard sanitary sewer and the University of Washington campus at 15th Avenue NE, conduct a meeting with the Resident Engineer to discuss and review the Work Plans and contingency plans. Prepare a fully detailed back-analysis which demonstrates the control of face pressure muck weights and grouting volumes and pressure.

3. Prior to the excavation beneath the University of Washington campus at 15th Avenue NE, conduct a meeting with the Resident Engineer to discuss and review the Work Plans and contingency plans to comply with the TBM tunneling duration limit of 304 days.

F. Daily Reports as Required by Quality Control.

3.02 CONSTRUCTION

A. Excavation:

1. Advance tunnel heading through all ground conditions encountered using Required Support Pressure to minimize Lost Ground as required to comply with ground movement limits.

2. Operate TBM with Required Support Pressure during TBM advance; Open Mode operation is not permitted during TBM advance.

3. Maintain a minimum excavation distance of 300 feet between TBMs measured along station in the north running tunnel from the Roosevelt Station TBM launch to STA 1310+00, from STA 1302+50 to STA 1300+00, for the Ravenna Sewer undercrossing, STA 1266+00 to the Brooklyn Station reception, from the Brooklyn Station TBM re-launch to STA 1252+00, and from STA 1213+00 to the University of Washington Station reception. Elsewhere maintain a minimum distance between TBMs of 3 tunnel diameters.

B. Face Support Application:

1. Provide Active Face Support by pressurized slurry or earth paste at all times during tunnel excavation; adjust as appropriate within improved ground if present adjacent to launching and receiving portal.

2. Modify Active Face Support pressure from that previously calculated to adapt to the actual ground conditions and groundwater pressure encountered, as necessary, to comply with ground movement limits and to ensure face stability and minimize Lost Ground at all times:
a. Operate the pressure control system to keep Active Face Support pressure within the following operational tolerances of target pressure specified for the TBM type utilized:

1) EPB TBM: plus or minus 0.3 bar.
2) Slurry TBM: plus or minus 0.1 bar.

3. Adjust composition and properties of the slurry (for Slurry TBM) to the local ground conditions and properties of the make-up water in order to achieve a reliable Active Face Support including impacts from tunneling through zones with high permeability ground and organic soils.

C. Tunnel Excavation under the Ravenna Boulevard sanitary sewer

1. Excavate and build rings through the station intervals indicated on a continuous 24-hour/day basis:
   a. For the north running tunnel: Station 1301+72 through Station 1300+72
   b. For the south running tunnel: Station 1301+91 through Station 1300+91

2. Apply bentonite to the Steering Gap in a controlled manner such that an even pressure is applied along the length of the TBM shield and monitor volumes to minimize losses into the tail void or into the excavation chamber.

3. Do not perform any inspection stops within the intervals indicated in 3.02 C. 1 a. and b.

D. Face Support during TBM Stoppage:

1. Control and stabilize the tunnel face during Inspection, Maintenance, and Boulder Stops, and any other heading or Excavation Chamber work using compressed air.

2. Prior to entry into the Excavation Chamber under compressed air, introduce bentonite slurry into the tool gap or flooded into the Excavation Chamber such that a substantial and continuous bentonite cake is formed on the tunnel face.

3. Apply calculated target air pressure within Excavation Chamber with supplementary face support, if necessary.

4. Prior to carrying out any work in the chamber, ensure a competent person conducts a Face Stability Assessment. Ensure the competent person immediately advises the Resident Engineer of any changes in compressed air pressure or abandonment of the entry due to ground conditions.

5. Compressed air support may be reduced or eliminated based on the evaluation of the competent person.

6. Maintain bentonite cake and supplementary face support during the Excavation Chamber entry.

7. Continuously control air pressure and compressed air consumption within a tolerance of plus or minus 0.05 bar for face support by compressed air.

8. Refill Excavation Chamber with earth paste or slurry and pressurize before restart of the TBM after Inspection, Maintenance, and Boulder Stops.
E. Support by Precast Concrete Segments:

1. Refer to Section 31 74 16, Precast Concrete Tunnel Lining.
2. Grip and erect segments in a manner to accurately position and align segments and gaskets within specified tolerances as specified in Section 31 74 16, Precast Concrete Tunnel Lining.
3. Handle segments to avoid damage.
4. Clean all faces of each segment and gasket prior to fitting adjacent faces together.
5. Lubricate key segment gaskets prior to installation.
6. Maintain the ring erection area free of debris and accumulations of muck and water prior to and during the ring building process.
7. Packing on the ring leading edge where propulsion cylinder shoes make contact is prohibited.
8. Where the tunnel exceeds specified tolerances, perform remedial work.
9. Perform plane checks as directed by the Resident Engineer.
10. Packing on the leading edge of the ring is prohibited unless directed by the Resident Engineer for the purpose of correcting the plane of the ring.
11. Perform grouting to meet segment Groundwater Seepage requirements per Section 31 74 16, Precast Concrete Tunnel Lining.

F. Tail Void Grout Injection:

1. Carried out such that complete filling and pressurization of the void is simultaneous with TBM advance in accordance with Section 31 73 23, Tail Void Grouting.
2. Stop the TBM advance when grouting equipment is not functioning.

G. Muck Handling:

1. Handle and convey muck through the Excavation Chamber and TBM to the ground surface.
2. Dispose of excavated materials in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.
3. Submit copies of disposal records in accordance with Section 01 55 00, Vehicular Access and Parking.

H. Removal of Water:

1. Remove all accumulating water and groundwater inflow from the TBM and tunnel using methods and equipment necessary to prevent damage to any portion of the work.
2. Disposal of all water per Section 01 57 24, Temporary Site Water Discharge.
3. Limit flows to requirements of Section 31 74 16, Precast Concrete Tunnel Lining.
I. Tolerances

1. Line and Grade:
   a. Control TBM position as required to maintain dynamic envelope of light rail vehicles and permit installation of precast concrete segment linings in accordance with requirements indicated and the following:
      1) Deviation not to exceed 4 inches in any direction from the DTA
   b. Make corrections with due consideration of required tolerances for the segmental lining, as specified in Section 31 74 16, Precast Concrete Tunnel Lining.

2. Heave and settlement per Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

3. Groundwater seepage per Section 31 74 16, Precast Concrete Tunnel Lining.

J. Prevention and Remediation of Lost Ground:

1. Measure and record the amount of muck using the Muck Control System.
   a. Calibrate the Muck Control System at regular intervals, but no less than monthly.
   b. Record the excavated volume of muck for each completed ring.

2. Immediately notify Resident Engineer and modify face support pressure or muck handling system as necessary for better control and to minimize Lost Ground at face if verified muck weight and volume exceeds theoretical excavation weight and volume by greater than ten percent per ring.

3. Fill voids within four hours and repair any damage to underground utilities, surface structures, roadways, or any other features resulting from Lost Ground, settlement, and heave. Work with the Resident Engineer to determine the most appropriate action including drilling and grouting from a surface location.

4. Document Lost Ground void filling and submit Lost Ground records within four hours of completing remedial work.

5. Work with Resident Engineer and owner of the structure or utility to determine what mitigation and repairs are required as a result of the Lost Ground.

6. For all losses and damage arising from Lost Ground including, but no limited to, damage to underground utilities, surface structures, roadways or any other feature that may occur in the prosecution of the work:

K. Ventilation System:

1. Operate the tunnel main ventilation system continuously 24 hours per day, seven days per week.

2. During extended periods of inactivity and when tunnel and associated excavations are unoccupied, the volumetric flow rate may be reduced to one-half that required during operation.

3. Advance the ventilation system continuously with the normal excavation cycle.
4. Operate and maintain mechanical ventilation systems in tunnel and portal excavations in which work of any kind is being performed.

5. Monitor the performance of the ventilation system as required by OSHA and WAC, and as often as deemed necessary to fully protect workers, but not less than once every seven calendar days to verify that it conforms to the minimum requirements.
   a. Measure the flow rate of fresh air delivered by the ventilation system at the following minimum locations:
      1) Within the TBM shield in the ring build area.
      2) In the tunnel at a position eight tunnel diameters behind the back end of the TBM trailing gear.
      3) In the tunnel at a position eight tunnel diameters from the nearest open portal.
   b. Perform weekly smoke tube tests in the tunnel heading to identify air recirculation and areas of dead air. Modify or adjust the ventilation system as necessary to eliminate deficiencies.
   c. Air monitoring equipment:
      1) Check all with a known mixture of gas and calibrate, if necessary, at least once every 30 calendar days.
      2) Maintain in accordance with the manufacturer's recommendations.
      3) Maintain calibration records and make available to the Resident Engineer on request.
   d. Maintain records of all observations, and make available to the Resident Engineer on request.

6. Report indications of combustible or toxic gas in tunnels and portals to the Resident Engineer immediately.

7. In the event of primary ventilation system failure for any reason, withdraw all persons from the tunnel. Permit limited access to those working to restore normal ventilation. Following restoration of ventilation flow, verify the air quality and modify ventilation system as required to meet OSHA and WAC requirements, prior to permitting re-entry of personnel.

8. After the tunnel is holed through, maintain appropriate air flow and/or OSHA minimums for the work activity being undertaken until the tunnel is completed and accepted.

9. Advise the Resident Engineer before the main ventilation system is reversed.

L. Movement Monitoring System:

1. Monitor, document, and evaluate movements of the ground, tunnel lining, adjacent property, and other pertinent facilities during the tunneling process observations as necessary for a controlled and safe tunneling operation.
a. Geotechnical instrument monitoring: Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

b. Survey Information: Section 01 71 23, Field Engineering.

M. Inspection Stop:

1. Plan for and obtain agreement from Resident Engineer for locations of all Inspection Stops prior to commencing TBM drives.
   a. Schedule of working hours and days of the week planned for tunnel excavation.
   b. Limited to locations adjacent to a subsurface investigation borehole as indicated in the Contract Documents.
   c. Geological conditions as indicated in the Contract Documents.
   d. For EPB and slurry TBM subsequent inspection stops within Roosevelt to University of Washington Station Tunnels:
      1) Prior to commencing tunneling beneath the University of Washington campus from the east side of 15th Avenue NE.
      2) At each of the proposed cross passage locations.

2. Use any inspection method considered useful to the Contractor, but include at least one visual method and direct measurement of cutter wear. Visual inspection methods could include either personnel access or the use of a remote camera.

3. Submit documentation report of all the items inspected and their condition within 24 hours of the inspection stoppage. Include:
   a. Written condition report of head, saddles, and other components.
   b. Details of cutting tool wear, including identification of any replaced during the stoppage.
   c. Photographs, video, or other record made during the inspection.

4. Document observed conditions during inspection stoppage, including face stability, groundwater inflows, and Excavation Chamber pressures.

N. TBM Maintenance:

1. Complete as often as necessary to keep the cutting tools, cutterhead, Excavation Chamber equipment, pressure sensors, muck handling equipment, and other TBM equipment in good operating condition, and as per manufacturers’ recommendations.

2. Test hydraulic oil, seal oil, and bearing lubricating oil and grease at least once per every 100 operating hours, monthly, or in accordance with manufacturer recommendations, whichever is more frequent. Maintain records of these tests and make available to the Resident Engineer upon request. Clearly indicate the contaminant levels and overall condition including changes since last testing and maintenance action indicated.
3. Do not conduct Maintenance Stops when the heading is below a water main, railway, highway, or settlement sensitive utility and ground cover, which is less than 50 feet between the crown of the outside of the tunnel and the invert of a structure, utility, or bottom of the roadway and railway including subgrade, unless appropriate ground treatment has been carried out in advance.

4. Modify the cutter types as needed to adjust for varying ground conditions.

5. Optimize cutting tools for best TBM performance with consideration of: production, cutter, and cutterhead wear, and fracturing of cobbles and boulders sufficiently at the heading for proper handling within the Excavation Chamber and mucking system.

6. Submit observed cutter and cutterhead conditions, face stability, groundwater inflows, Excavation Chamber pressures, and all maintenance work completed during each maintenance stop.

7. Recalibrate or replace sensors being logged by the data acquisition system upon discovery of damage or the observation of erroneous readings.

O. Boulder Removal:

1. Perform when a boulder is detected which cannot be ingested by the screw conveyor or stone crusher.

2. Do not conduct Boulder Stops when the heading meets criteria listed in Article 3.02 L herein.

3. Blasting is prohibited. Use splitting, jack-hammering, sawing, chiseling, or other acceptable means for cutting, fracturing, and removal.

4. Document observed face stability, groundwater inflows, and Excavation Chamber pressures for work completed during Boulder Stops.

P. Electrical System Monitoring:

1. To remain acceptable for use in Class 1 Division 2 hazardous locations, maintain Essential Services electrical equipment as indicated:
   a. Inspect as often as deemed necessary to protect workers, but not less than once every seven days by a competent person.
   b. Maintain in condition suited to its intended use.
   c. Inspect explosion-proof enclosures for loose or missing screws, for damage to gaskets, threaded connections, covers, or seals, and for other impairments to a tight condition.
   d. Inspect cables for cuts, abrasions, and other impairments.

2. Maintain records of these inspections and make available to the Resident Engineer on request.

Q. Provide for safe access and egress of personnel to and from the heading. Include procedures for personnel working in all tunnel locations and include, as appropriate, separate walkways, refuges, personnel transfer equipment and authorization systems for working and walking on the track way.
1. Provide a continuous temporary safety walkway along the tunnel which is not within the envelope of the mucking or transport equipment and meets the height of the TBM gantry walkway.

2. Walkway platform: Not less than 2 feet wide and equipped with toe boards and hand rails on the track side of the walkway.

3. Provide walkway access points at tunnel entry, along the tunnel at the proposed cross passage locations and at the rear of the TBM gantry to provide safe access to tunnel invert or cross passage locations.

R. Temporary Tunnel Sump:

1. Provide a temporary tunnel sump sized to fit within the tunnel envelope located at the tunnel low point.

S. Tunnel Launch at Roosevelt Station and Re-Launch at Brooklyn Station:

1. Provide details of ground improvement or ground support and dewatering to the extent permitted by Section 31 23 19, Dewatering, for ground and groundwater control at the launch structure prior to tunnel re-launch.

T. Tunnel Reception:

1. Provide details of ground improvement or ground support and dewatering to the extent permitted by Section 31 23 19, Dewatering, for ground and groundwater control at the receiving structure prior to tunnel reception.

U. Segment Repair and Lining Clean-Up Prior to installation of final track bed and walkway: Section 31 74 16, Precast Concrete Tunnel Lining.

V. Daily Meetings: Conducted between the Contractor and Resident Engineer to discuss safety, quality, operating parameters, instrumentation monitoring, production and submission of reports from previous day(s) production.

3.03 INSTALLATION

A. Concrete Invert and Walkway

1. Pour Cast-in-place concrete in accordance with Section 03 30 00, Cast-in-Place Concrete.

2. Before placement of concrete, take care to determine that all embedded items are firmly and securely fastened in place as indicated on the Contract Drawings.

3. Drill dowels for safety walkway at drilling locators as indicated on the Contract Drawings. Clean holes and grout dowels in accordance with the grout manufacturer's recommended procedure.

4. Finish concrete as follows, in accordance with Section 03 35 00, Concrete Finishing:

   a. Invert slab: Troweled Finish, except under rail plinths. Under rail plinths provide scratched finish.


   c. Side of safety walkway: Smooth Form Finish.
5. Tunnel Surveys: As-Built Invert Survey
   a. Survey as-built tunnel invert as follows:
      1) Measure distance from track centerline to face of walkway as indicated in the Drawings at 10-foot intervals.
   b. At same location, take invert elevations at offsets of 2 feet 4-1/4 feet either side of theoretical track centerline.

6. Tunnel Surveys: Brass Plug Installation Survey
   a. Description:
      1) Use brass plugs to provide a permanent record of reference line sub tangents and track centerline sub tangent locations.
      2) Use Brass plugs (BPs) consisting of a 1/2-inch Star Tampin and a 1/2-inch diameter anchor bolt, 1-1/2 inches in length, installed so that top of plug is flush with adjacent concrete surface.
   b. After completion of invert and safety walkway concrete, install BPs at following locations:
      1) In tangent track areas at maximum station intervals of 300 feet, place two BP witness monuments on a single witness line set at right angles to centerline of track. Place one BP on safety walkway and one on the invert concrete at random offsets as directed by the Resident Engineer. Record station, two offset distances and elevations.
      2) In curved track areas, at all PIs and sub-PIs along track centerline traverses as directed by Sound Transit, place two BP witness monuments on a single witness line set through PI at random angles to track center line tangents. Place a BP on safety walkway and another on concrete invert at random offsets to PI. Record angles between witness line and ahead and back tangents. Record two offset distances and elevations.

B. Tunnel Handrail
   1. Fabricate and install tunnel handrail to the requirements for Metal Handrails, non-public exterior (galvanized) as specified in Section 05 52 14, Metal Handrail except as modified below.
   2. Anchors, Fasteners and Accessories: Comply with the requirements of Section 05 52 14, Metal Handrails.

3.04 FIELD QUALITY CONTROL
A. General:
   1. TBM Data: Review data transmitted real-time for TBM system monitoring and provide complete unaltered digital records in an agreed format directly to Resident Engineer.
   2. EPB Muck Control:
a. During the excavation of the tunnel, observe the muck passing over the belt for changes in its appearance.

b. Ensure the Muck Control System provides data on a ring by ring basis to the operator display and data logger for both instantaneous and total weight. Also take volume measurements by observation of the muck car filling. Record both measurements on the ring reports and used for calculated unit weight.

c. Determine bulking factor of the excavated soil for each ring and compare to the actual muck volume observed.

d. Promptly notify Resident Engineer and provide documentation if calculations indicate that actual volumes or weights for a shove exceed theoretical by more than ten percent.

3. Slurry Muck Control:

a. Control the material properties of the slurry every time, fresh suspension is being mixed and once every shift. Record the slurry density once per shift.

b. Determine, monitor, and test material flow characteristics such as density, filtrate loss, viscosity, yield point and others as identified within the Submittal with Acceptable Disposition.

c. Record total weight of excavated material on a ring basis.

d. Record the total weight of the discharged material on a shift basis.

e. Record the total volume of bentonite slurry added to the system on a shift basis. Promptly report bentonite losses in writing to the Resident Engineer.

f. Maintain Slurry Muck Control records on a shift basis of quality control tests including slurry density and volume of slurry and conditioner used and make available to the Resident Engineer upon request.

4. Daily Reporting and Documentation during Tunneling:

a. Shift Reports:

1) Submit the daily shift reports by 10 am the following day in both an agreed digital and hardcopy format and include the following information:

a) Date, location, shift, beginning and ending face station, list of personnel by name, classification, and function working that shift, list of the number and type of equipment, including amount of and reason for any idle or down time, list of all materials used in the work.

b) Description of materials being excavated, volume of excavated materials using methods as mutually agreed when not otherwise specified.

c) Description and locations of Lost Ground, water inflows and other events.
d) Cutting tool and muck system component changes, including time and date of replacement, cutter or component position or number, and reason for change.

b. Submit Ring Reports in both an agreed digital and hardcopy format and include the following:

1) Date, shift, ring number, beginning and ending face station, start and end time for excavation and ring erection, face support pressure, total excavated weight and volume, type and total volume of conditioners injected, calculated unit weight, GBR unit weight, total volume and pressure of grout injected through each line, bentonite injected, observed material density, and calculation of bulking factor.

2) Guidance system information, including present and predicted position, propulsion and articulation cylinder extensions, ring gap before and after ring erection, key position, and roll of ring.

3) Observations and damage to precast segments or gaskets:
   a) Record of segments damaged due to transport, handling or installation.
   b) Locations of leakage, including estimated rates and remediation actions. Include results of any remediation actions taken.

c. Provide Air Quality Monitoring Report in both an agreed digital and hardcopy format:

1) Maintain records of air quality measurements and reports and make available to the Resident Engineer upon request.

2) Indications of combustible or toxic gas in tunnels or portals to the Resident Engineer immediately on the same day that these indications occur.


e. When feasible, combine reports.

5. Daily Soil Sampling: In accordance with Article 1.04. P herein and the following minimum requirements:

a. Take a muck sample directly from the conveyor when a change in appearance is noted by the Contractor or when directed by the Resident Engineer.

b. At a minimum, take a 0.5 cubic foot sample once per each day of excavation. Identify samples to location and date. Place sample within watertight plastic bag, and seal. Identify location on the bagged sample. Provide bag sample to Resident Engineer.

c. Note GCS settings along with stationing and other pertinent data on the soil sample report form and include as part of the daily report submittals.

d. Testing:
1) Provide an Independent Testing Laboratory for soil samples.

2) Carry out soil classification studies on each soil sample taken including:
   a) Atterberg limits on fine grained soils in accordance with ASTM D4318.
   b) Soil gradation in accordance with ASTM D422.
   c) pH testing of soil in accordance with US EPA SW-846, Method 9045D.

B. Tunnel Surveys: As-Built Tunnel Lining Survey and Final Alignment

1. Immediately after completing each tunnel, carry out a 1:50,000 survey utilizing a closed traverse to establish accurate line, elevation, and stationing. Make survey agreement with the Resident Engineer and submit with as-built data to compare with theoretical setting out data.

2. On this survey locate every third lining ring through the tunnel. Where the survey shows that a section of tunnel is outside specified tolerances, locate every ring throughout that section plus a length of ten rings on each side. Include within this survey the following:
   a. Horizontal offsets from theoretical centerline to each inside face of tunnel.
   b. Vertical offsets to crown and invert measured from theoretical centerline.
   c. Four radial offsets through theoretical centerline measured at angles of 45 degrees from vertical.
   d. Measure horizontal stationing of points where measurements are taken and at openings and at all other features as required by the Resident Engineer.

3. Perform survey so that results may be entered directly into a computer program to check tunnel alignment.

4. For all measurements taken, calculate differences between actual and theoretical positions. Submit all information together with copies of a graphical representation of differences from theoretical.

5. Sound Transit will assess above information.
   a. Assessment of any length of tunnel cannot be completed until as-built survey data have been supplied for at least 250 feet into adjacent lengths of tunnel.
   b. Sound Transit may design and adopt an amended alignment at Sound Transit’s sole discretion.
   c. Pay all of Sound Transit’s costs that are associated with designing and adopting an amended alignment.

6. If an amended alignment is adopted, carry out all subsequent work in accordance with that amended alignment.
7. **Survey:**
   a. Coordinate survey work with Section 01 71 23, Field Engineering.
   b. Provide surveyor and Resident Engineer access and assistance as necessary for confirmation of the tunnel alignment and stationing.
   c. Immediately initiate alignment corrections and alignment control changes if a survey error and out of tolerance alignments are identified. Notify the Resident Engineer immediately upon discovery of TBM out of tolerance.
   d. Be responsible for the accuracy of the work and for correcting it, as required.

C. **Remedial Measures:**
   1. **Precast Segmental Lining Defects:** Quality and water tightness in accordance with Section 31 74 16, Precast Concrete Tunnel Lining.
      a. Promptly stop or control leakage causing piping or erosion of fines during tunneling to prevent Lost Ground.
      b. Repair unacceptable segment spalling and damage prior to invert installation.
   2. **Grout to fill voids** in accordance with approved submittals.

D. **Ground Movement:** refer to Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.

3.05 **CLEANING**
   A. Perform regularly scheduled tasks to:
      1. Clean the tunnel interior and invert muck, grout, debris, and other foreign materials.
      2. Maintain sumps, collection points, and pumps clear of trash and in good operating order.
      3. Maintain clear passage of the flow of personnel, equipment, and materials.

3.06 **PROTECTION**
   A. Whenever there is a condition which is likely to endanger the stability of the excavation or adjacent work or structures, notify the Resident Engineer and work with a full crew for 24 hours per day including weekends and holidays without interruption until those conditions are mitigated.

   B. Follow the Tunnel Safety Plan for tunnel evacuation and for tunnel re-entry in the event that the air monitoring system alarms or automatic power shutdown occurs. Post the evacuation and re-entry plans in a readily visible location at the entrance portal. Train workers in tunnel evacuation procedures.

   C. Give tunnel crews daily safety briefings and sufficient time at shift change hand-over to identify any hazardous conditions or safety issue that may exist and have not been corrected.
D. Notify the Resident Engineer immediately upon:

1. Encountering an emergency condition likely to endanger the tunnel integrity, including but not limited to: seepage with soil erosion or piping of fines at heading, tail seal seepage, precast concrete segment joint seepage, portal seal seepage, excessive lining deformations, significant lining cracks and other detrimental observations.

2. Encountering an emergency condition likely to endanger structures adjacent to the tunnel axis.

3. Any TBM or tunnel air quality alarm or warning.

END OF SECTION
SECTION 31 71 23
TUNNEL EXCAVATION BY SEQUENTIAL EXCAVATION METHOD

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for excavation and support of the cross passages utilizing the Sequential Excavation Method (SEM).

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 57 24, Temporary Site Water Discharge
2. Section 31 09 13.50, Tunnel Instrumentation and Monitoring
3. Section 31 20 00, Earth Moving
4. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine
5. Section 31 74 19.05, Shotcrete for SEM Tunnels
6. Section 31 74 19.10, Initial Shotcrete Tunnel Lining
7. Section 01 74 01, Excavation Spoils and Muck Disposal.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents. In case of a conflict between the requirements of this Section and those of a listed document, the requirements of this Section shall prevail.

1. American Society for Testing and Materials (ASTM)
   a. ASTM A36 Standard Specification for Carbon Steel
   b. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   c. ASTM A82 Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
   d. ASTM A185 Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete
   e. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105ksi Minimum Tensile Strength
   f. ASTM A497 Standard Specification for Steel Welded Wire Reinforcement, Deformed, for Concrete
g. ASTM A501 Standard Specification for Hot-formed Welded and Seamless Carbon Steel Structural Tubing

h. ASTM A615 Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

i. ASTM C109 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars Using 2-inch or [50mm] Cube Specimens

j. ASTM C144 Standard Specification for Aggregate for Masonry Mortar

k. ASTM C150 Standard Specification for Portland Cement

2. American Institute of Steel Construction (AISC):

3. American Concrete Institute (ACI)
   a. ACI 506.2 Specification for Shotcrete
   b. ACI 506R Guide to Shotcrete

4. Washington Administrative Code (WAC)
   a. Chapter 296-350 WAC, WISHA Administrative Rules

5. Revised Code of Washington (RCW)
   a. Chapter 49.24 RCW Health and Safety, Underground Workers.

1.03 DEFINITIONS

A. Cross Passage Type: Either the typical cross passage configuration or low point sump cross passages 21 and 31, as indicated in the Contract Documents.

B. Theoretical Excavation Line: Theoretical line of excavation inside of which no earth or surrounding ground shall protrude.

C. SEM Excavation: Tunnel excavation using sequences and support measures as shown on the drawings for various support categories. Installation of pre-support, sequential excavation of limited round lengths, with support installed immediately following excavation.

D. Excavation and Support Sequence: Prescribed sequence to complete the cross passage excavation and initial support lining using SEM.

E. Length of Round: Length of exposed ground opened up during one excavation increment and immediately sealed with flashcrete, as indicated.

F. Over-excavation: Intentional or unintentional excavation of ground beyond the theoretical excavation line.

G. Ground Improvement: Modification of naturally existing soils by dewatering, grouting or other approved methods.

H. Pre-Support: Support elements installed prior to excavation of the ground, including rebar spiling, grouted pipe spiling, and metal sheeting.
I. Flashcrete: Minimum two-inch thick layer of steel fiber reinforced shotcrete placed immediately after excavation on exposed ground surfaces as indicated.

J. Initial Shotcrete Lining: Shotcrete lining of minimum thickness and reinforcement as shown on the Contract Drawings.

K. Final Lining: Reinforced concrete or shotcrete lining placed after installation of initial shotcrete lining and waterproofing system.

L. Groundwater Control Measures: Work and equipment required to collect and remove groundwater ahead of the face of excavation or penetrating into the cross passage. Included are temporary construction drainage and gravity dewatering from well points, vacuum dewatering, drainage mats, PVC-hoses or similar materials used to collect and drain off groundwater from areas at either the excavated ground surface before applying shotcrete lining to prevent hydrostatic pressure build-up behind the shotcrete lining and/or for dewatering of seepage through the shotcrete lining, including pumps as required to convey seepage to discharge locations.

M. Rebar Spiling: Reinforcing bar without end hardware driven into the ground, or installed and grouted into pre-drilled holes ahead of cross passage excavation.

N. Grouted Pipe Spiling: Perforated steel pipes driven, placed in pre-drilled holes, or self-drilling anchors installed ahead of the cross passage excavation and grouted in place.

O. Metal Sheets: Overlapping or interlocking steel sheets driven above or outside the lattice girders into the ground ahead of the next round to be excavated.

P. Face Stabilization Wedge: Unexcavated portion of the heading temporarily left in place to enhance face stability.

Q. Pocket Excavation: Excavation sequence where the excavation face is split into smaller areas (pockets) of excavation which have flashcrete applied immediately after excavation. Pocket excavation is carried out in a series along the tunnel circumference facilitating the installation of shotcrete support.

R. Grouting: Permeation grouting ahead of the face to stabilize loose or granular soils by injection of cementitious or chemical grouts.

S. Vacuum Dewatering: Installation of wells surrounded by a filter medium to dewater soil layers by means of maintaining a vacuum in the well.

T. Probe Drilling: Geologic exploration of ground conditions by means of probe holes.

1.04 SUBMITTALS:

A. Qualifications:
   1. SEM Superintendent
   2. SEM Surveyor
   3. SEM Tunnel Project Engineer

B. SEM Work Plan for cross passage Excavation

C. Shop drawings with detailed description for the sequence, materials, and installation procedures for the SEM work for each cross passage.
D. Certifications

E. Reports:
2. Groundwater Monitoring Reports.
3. Excavation Summary Reports for each cross passage.

F. Contingency Plans:
1. Encountering loose or unstable soil at cross passage excavation.
2. Unanticipated groundwater inflows during cross passage excavation.

1.05 QUALITY ASSURANCE

A. SEM Tunnel Project Engineer shall have a minimum 10 years experience in underground construction, three years experience in SEM construction, including at a minimum two completed projects utilizing SEM and Shotcrete similar to that indicated.

B. SEM Surveyor: Shall be a licensed Professional Land Surveyor registered in the State of Washington, with a minimum of 10 years experience in underground construction, including at least three projects where cross passages were constructed as indicated.

C. Certify, through records of training and a written statement that Contractor’s SEM crew are prepared and equipped to apply or install all support measures indicated for each Cross Passage Type.

D. SEM Superintendent shall have a minimum 12 years construction experience utilizing SEM with shotcrete support.

1.06 SEM WORK PLAN FOR CROSS PASSAGE EXCAVATION

A. Include drawings, sketches, product data and written text describing the overall approach to the SEM work. Include:

1. Statement of anticipated conditions for each cross passage. Include confirmatory probing data obtained during Bored Tunneling. Refer to Specification Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

2. For excavation and support sequences differing from the ones given in the design documents, drawings and calculations, signed and sealed by a Professional Engineer registered in the State of Washington, which show required initial shotcrete thicknesses, stages of excavation and support, anticipated deformations, and other information pertinent to cross passages construction.

3. Required construction tolerances dictated by the excavation, support methods required for break-out from the Bored Tunnels.

4. Deformation predictions for both Bored Tunnel and SEM linings; and how the dimensions and materials used will accommodate same.

5. Proposed materials, facilities, and equipment to be used.
6. Key excavation plan including proposed excavation and support sequence. For each type of cross passage show:
   a. Sequence and timing of top heading and bench/invert excavation and anticipated advance rates.
   b. Methods of construction including shotcrete lining installation details, all pre-support and support elements;
   c. Methods of construction for break-outs of running tunnels:
      1) Measures to support the Bored Tunnel segmental lining.
      2) Removal of lining segments.
      3) Protective measures for lining segments at break-outs.
      4) Excavation and support sequences at break-outs.
      5) Void grouting.
      6) Method of controlling line and grade of linings.
      7) Details on excavation and removal of all temporary pre-support and temporary shotcrete.
      8) Installation of in-tunnel water control measures, including well points, temporary sumps, construction drains.
      9) Vacuum dewatering material specifications and procedures.

B. Equipment:
   1. Excavation equipment for all SEM tunnel excavations including make and model numbers, manufacturer’s literature and maintenance record.
   2. Shotcrete batching plants.
   3. Shotcrete pumps.
   4. Drilling Equipment.
   5. Dewatering Equipment.

C. Plans detailing Groundwater Control Measures to be used for each type of cross passage, including drain pipes, drainage mats, temporary sumps, construction drains, pumps, vacuum dewatering, procedures to be followed, and standby power supply.

D. Materials:
   1. Materials for grouted pipe spiling and permeation grouting.
   2. Lattice Girders.
   3. Spiling
   4. Metal Sheets
1.07 CONTINGENCY PLANS

A. Prepare Contingency Plans to address unanticipated conditions which may occur during the SEM work. At a minimum, include plans for:

1. Unanticipated loose and unstable soils, face instability.
2. Unanticipated groundwater inflows.
3. Lining deformations which exceed specified limits.
4. Surface/building deformations beyond specified allowable limits.

B. Include steps used to assess conditions that require additional measures not described herein.

C. Address modifications in the proposed excavation sequences and lining requirements, that would be needed to continue under safe working conditions for each of the unanticipated conditions.

D. Include in each Contingency Plan:

1. Name and qualification of personnel responsible for implementing contingency procedures.
2. Surveillance during stoppages such as weekends and holidays as well as directed stoppages.
3. Measures required to be put in place prior to the re-start of excavation.

1.08 DELIVERY, STORAGE, AND HANDLING

A. Have adequate supply of required materials for cross passage Support ready for application at all times during cross passage excavation as follows:

1. Flashcrete, Shotcrete: Have sufficient amount of steel fiber reinforced flashcrete and shotcrete available at the cross passage heading to be applied at each excavation face during the entire excavation period for immediate application to complete excavation round.
2. Reinforcement: Have lattice girders and other reinforcing materials readily available on site for next excavation round of each heading before commencing excavation.
3. Groundwater Control: Have sufficient drainage mats, pipes, hoses, well points, pumps and other materials for installation and operation of water control available on site before commencing excavation.

B. Store materials in accordance with the Suppliers’ specification. Maintain materials in a clean and undamaged condition.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Shotcrete
   1. See Section 31 74 19.05, Shotcrete for SEM Tunnels.

B. Initial Shotcrete Lining
   1. See Section 31 74 19.10, Initial Shotcrete Tunnel Lining.

C. Rebar Spiling
   1. No. 10 standard deformed steel reinforcing bars with pointed tip, 12 feet in length, conforming to ASTM A615, Grade 60.

   2. At breakout from TBM tunnels. No. 10 standard deformed steel reinforcing bars with pointed tip, 10 feet in length, or 24 feet in length with couplers as required for the different support categories, conforming to ASTM A615, Grade 60.

   3. Self-drilled and grouted anchors or bolts may be used as approved by the Resident Engineer.

D. Grouting Pipe Spiling
   1. Pipes:
      a. Perforated steel pipe.
      b. Diameter: two inches minimum.
      c. Typical length: 12 feet.
      d. Length at TBM breakout location: 10 feet, or 24 feet in length with couplers as required for the different support categories.
      e. Steel: black, ASTM A53.

   2. Grout Mix Design: Ingredients that are compatible, non-corrosive to steel and free from calcium chloride.
      a. Minimum compressive strength: 100 pounds per square inch (psi) in 4 hours.
      b. Water: Potable.
      c. Cement: ASTM C150. Use Type I or III cement, fresh and not containing any lumps or other indication of hydration or “pack set”.
      d. Sand: ASTM C144, except maximum particle size limited to Size 18 sieve.

E. Metal Sheets
   1. Steel, ASTM A36, minimum 3/16 inch thick.
2. Overlapping or interlocking sheets.

F. Drainage Mats

1. ENKADRAIN, AKWADRAIN, MiraDRAIN, or Sarnafil Drainage Panel or approved equal.

G. Well Points:

1. Pointed steel dewatering pipes of minimum 2 inches diameter to be driven or drilled into the ground.
2. Perforated or slotted to allow sufficient dewatering of perched water in sand/silt lenses or sand/silt layers and minimize migration of fines.

H. Vacuum Dewatering

1. Vacuum wells: Two inch diameter rigid PVC or steel pipe with filter fabric, slotted screen, length as required and approved by the Resident Engineer.

2. Screen-filter criteria:
   a. Slots: Minimum filter diameter of 85 percent size (D₈₅) / slot width greater than 1.2.
   b. Holes: Minimum filter D₈₅ / hole diameter greater than 1.0.

3. Filter-aquifer criteria:
   a. Maximum filter diameter of 15 percent size (D₁₅) / minimum aquifer D₈₅ less than 5.
   b. Maximum filter diameter of 15 percent size (D₅₀) / minimum aquifer D₅₀ less than 25.
   c. Minimum filter D₁₅ / maximum aquifer D₁₅ greater than 5.

4. Use shotcrete or other sealant to seal the vacuum well to allow the build-up of vacuum.

PART 3 - EXECUTION

3.01 GENERAL

A. Temporary Ventilation

1. Provide, operate and maintain for duration of the project a temporary ventilation system that will conform to RCW code health and safety requirements of jurisdictional authorities or specified by Sound Transit.

2. Perform air quality testing daily for toxic and hazardous gases and other atmospheric impurities. Maintain records of all air quality testing, and make available to the Resident Engineer upon request.

3. Prepare a daily Excavation Report which includes the following information:
Face Mapping: Prepare a geologic map of each cross passage heading once per shift and documentation reporting all pre-support and support measures for each heading.

1) Signed by SEM Tunnel Project Engineer and SEM Superintendent.

B. Prepare an Excavation Summary Report on geologic conditions encountered, support and pre-support measures installed and problems encountered after completion for each cross passage within 30 days of completion of the shotcrete lining of same.

C. Observe and record average flow rates and time of operation of each dewatering system used. Provide appropriate devices, such as flow meters, for observing flow rates. Prepare a daily Groundwater Monitoring Report during operating period of each dewatering system. Use format approved by the Resident Engineer.

D. SEM Tunnel Project Engineer shall perform the following:

1. Supervise excavation to ensure the safety and quality of construction.
2. Devise and implement contingency procedures as required by ground conditions or directed by the Resident Engineer.
3. Coordinate remedial measures when ground loss at tunnel heading or instability of tunnel occurs, or when they appear likely.
4. Prepare Daily Excavation Reports.
5. Evaluate instrumentation readings and submit monitoring reports as specified elsewhere.
6. Prepare Excavation Summary Reports.
7. Be available on site at all times during all SEM related excavation

E. Safety Requirements

1. Perform Work in a manner that minimizes safety hazards and exposure of personnel and equipment to hazardous and potentially hazardous conditions.
2. Assess all ground and groundwater conditions, ground movement, lining deflection and surface deformations at all times during the construction period and act prudently and react swiftly to all indicators and conditions.
3. Provide safe work spaces, temporary platforms and stands at all times.
4. Illuminate all underground spaces sufficiently to carry out inspections at all times during the construction period.
5. In case of emergency or work stoppage likely to endanger excavation or adjacent structures, continuously maintain full work force 24 hours per day including weekends and holidays until emergency or hazardous conditions no longer jeopardize stability and safety of the structures.
6. Support ground continuously in a manner that prevents loss of ground, keeps lining perimeters and maintains stability of tunnel faces, and other underground openings.
F. Detection of Movement

1. Install and monitor instruments shown and in accordance with Section 31 09 13.50, Tunnel Instrumentation and Monitoring.

3.02 EXCAVATION AND SUPPORT

A. Expect excavation in all materials identified in the GBR.

B. Excavate to excavation limits as indicated on the Contract Drawings:

1. Use equipment and methods that do not damage previously placed reinforcing bars, lattice girders, and instrumentation in the vicinity of the tunnel circumference.

2. Grades and dimensions as indicated on Contract Drawings do not include tolerances for construction and deformation of the excavated opening. To maintain the theoretical dimensions required, over-excavation, which also allows space for steel parts protruding from the shotcrete lining, including the protection and smoothing layers for the waterproofing system, shall be accounted for.

3. Ensure neither the shotcrete lining nor other support measures intrude into clearances required for the placement of the final lining.
   a. Total unsupported length shall not exceed the maximum round length as shown on the Contract Drawings plus a maximum handling space of 18 inches.

C. Temporary Invert Protection:

1. Protect the initial shotcrete lining in the invert area of all cross passages from damage caused by construction equipment traffic until placing of the final invert concrete by means of a working slab.

2. Utilize gravel, or other suitable material approved by the Resident Engineer with a minimum thickness of two feet.

D. Dispose of excavated material in accordance with requirements indicated in Section 31 20 00, Earth Moving.

E. Probe Drilling

1. For Probe Drilling of holes ahead of the excavation face, use rotary drilling techniques that are intended to confirm the predicted geological situation and to detect groundwater, sand lenses, zones of wet silt, and other potentially unstable soils.
   a. Notify the Resident Engineer prior to start of Probe Drilling.
   b. Locate the probe holes as indicated in the Contract Documents or as approved or directed by the Resident Engineer.
   c. Core drilling is applied for additional exploration and probing purposes, the main objective being to recover cores with a minimum diameter of 3-1/2 inches. Adapt the drilling pressure during drilling to varying ground conditions. Avoid excessive pressure as well as core compression. Use dry core drilling method where feasible. Extract cores over the defined probe length. Place cores in foil lined cases, label with permanent writing.
and make available for inspection immediately after extraction. Take color photos immediately after placing the cleaned cores into the marked casings using a tripod which allows for a perpendicular shot of the cores. Store core cases on site to render them accessible for inspection at all times. Keep an accurate log from each drilling operation indicating drilling progress as related to time, installation and removal of core sample, advancing of casing tube, description of core using the Unified Soil Classification System and all extraordinary events such as water ingress or smells. Submit the logs to Sound Transit within 24 hours after completion of the respective core drilling.

d. Position and number of probe drill holes as shown and specified in the Contract Documents. Alter position of probe drill holes as approved or directed by the Resident Engineer.

e. Where a probe hole indicates water inflow apply further investigation by drilling an additional probe hole approximately 2 feet below the water bearing probe hole. Repeat this procedure until invert level of the heading or the bottom of the water bearing strata is reached. Install and grout in place a vibrating wire piezometer in the lowest water bearing probe hole according to manufacturer’s specification. Operating pressure range of the piezometer shall be a minimum of 1.5 times the cross passage depth below groundwater.

f. Interpret cores and discharge of probe holes with regard to soil behavior during excavation ahead of the tunnel heading.

2. Drillings for drainage (without core extraction):

a. Minimum diameter shall be 3-1/2 inches.

b. Prepare a log of the drilling indicating drilling progress, loose ground, voids, installation of casing tubes, observation of drilling water, water ingress and any extraordinary events.

F. Groundwater Control Measures – In-Tunnel Water Control

1. Drain, collect and pump out of the cross passage all infiltrating groundwater.

2. Remove groundwater and construction water from the operation as quickly as possible without causing damage.

3. Dispose of groundwater and construction water in accordance with Section 01 57 24, Temporary Site Water Discharge.

4. Prior to application of the shotcrete lining, collect all seeping groundwater or local groundwater inflow by means of drain hoses and/or drainage mats to prevent build-up of hydrostatic pressure behind the shotcrete lining and deterioration or reduction of the strength properties of the fresh shotcrete.

5. Collect water seepage through shotcrete and drain away by means of drain hoses.

6. Install and maintain at all times temporary drainage systems to control inflow of water into the excavation in order to permit all work to be performed in dry conditions.
7. Vacuum dewatering: Install vacuum wells as indicated or as required by hydrological conditions.

G. Excavation Sequence and Support Measures

1. Follow the excavation and support sequence for cross passages as indicated.

2. Evaluate the ground conditions encountered and confirm that Cross Passage Support Type indicated is appropriate:
   a. Review Probe Drilling data and results of the drilling for drainage pipes and spiling through bored tunnel concrete linings.
   b. Continuously review conditions encountered as the bored tunnel lining is broken out and removed.

3. Install face support of steel fiber reinforced shotcrete for work stoppages longer than 24 hours as indicated in the design drawings.

4. Top Heading, Bench-Invert Excavation:
   a. Use top heading, bench-invert excavation sequence and maximum round lengths as indicated. Apply a minimum two inch layer of Flashcrete on all exposed ground surfaces immediately after excavation to seal and protect ground from the deleterious effects of exposure (e.g. initial loosening, moistening or desiccation).

5. Initial Shotcrete Lining,
   a. Install after installation of the flashcrete.
   b. Grout voids behind the shotcrete lining caused by erosion or fallouts of soil behind the lining.

6. Rebar Spiling: Install by driving the spiles into the ground ahead of the tunnel excavation face or inserting them into pre-drilled holes as indicated. Fill pre-drilled holes with grout prior to rebar insertion. Self-drilled grouted anchors may be used in lieu of rebar spiles as approved by the Resident Engineer.

7. Grouted Pipe Spiling: Install by driving or jacking the perforated steel pipes into the ground ahead of the face or inserting them into pre-drilled holes as indicated. Grout the pipes through the perforations to achieve permeation and compaction of soil around the spile. Adjust grouting pressure as required to suit ground conditions.

8. Face Stabilization Wedge: Leave wedge of unexcavated material in place during excavation to support the face as indicated.

9. Pocket Excavation: Excavate soft or loose soil in partial drifts and immediately support with flashcrete as indicated.

10. Metal sheets: Install by driving the sheets into the ground ahead of the excavation face or as support for the bench, invert excavation as indicated. Grout behind metal sheets to fill any void between metal sheets and soil.

11. Grouting: Permeation grouting ahead and in the vicinity of the tunnel face in order to stabilize zones of loose soils as shown and specified in the Contract
3.03 FIELD QUALITY CONTROL

A. Do not allow initial shotcrete to encroach on final lining clearance line as shown in the Contract Documents.
   1. Submit survey reports and plotted profiles no later than 14 days after excavation.

B. Document stability of Cross passages by monitoring as specified. Prove the absence of any continuing and significant deformation before installing the waterproofing system and the final lining.
   1. Submit monitoring protocols as part of the Daily Excavation Reports.

C. Allowable Tolerances:
   1. Place initial shotcrete lining to the following tolerances (including lining deformations):
      a. Deviation of tunnel alignment from theoretical line or grade shown in the Contract Documents as measured from working point of tunnel: One inch.
      b. Variation in thickness of lining at any point: Minus zero inches.

D. End of shift:
   1. Do not leave the work site each day until satisfied that all excavated areas have been supported as specified.
   2. Do not leave exposed, un-shotcreted surfaces except where indicated in the Contract Documents.
   3. Install the entire structural lining system (welded wire fabric, lattice girders and shotcrete) prior to leaving the work site each day.

END OF SECTION
1.01 SUMMARY

A. This Section includes the Contract requirements, procedures, and training for providing initial First Responder Level (FRL) fire and life safety tunnel rescue actions at the site prior to the arrival of the Seattle Fire Department (SFD) Tunnel Rescue Team.

1. Contractor is responsible for cost of providing First Responder Level fire and life safety tunnel rescue, and the coordination of the requirements of same with the SFD’s Tunnel Rescue Teams.

2. Sound Transit is responsible for the cost of work performed by SFD, which includes providing the project’s Tunnel Rescue Teams, and the training of same.

B. This Section is intended to supplement and reinforce the requirements of MSHA 30 CFR 49 for this Contract.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine
2. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method

1.02 REFERENCES

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

1. Mine Safety and Health Administration (MSHA)
   a. 30 CFR 23 Telephones and Signaling Devices
   b. 30 CFR 49 Mine Rescue Teams
   c. 42 CFR 84 Approval of Respiratory Protective Devices

2. Washington Industrial Safety and Health Act (WISHA)
   a. WAC 296-155-730 Tunnels and shafts, Section 10 Rescue Teams

1.03 DEFINITIONS

A. First Responder Level (FRL) tunnel rescue: The initial fire and life safety actions provided by the Contractors on-site personnel in the event of an emergency occurring within the Site underground environment in the time period prior to the arrival of the SFD Tunnel Rescue Team.
B. Primary Tunnel Rescue Responder: Tunnel rescue services coordinated and provided by the SFD Tunnel Rescue Team in the case of a notified emergency occurring in the Site underground environment.

C. Site Underground Environment: Brooklyn and Roosevelt Station box excavations, twin running tunnels between Roosevelt and University of Washington stations, and associated cross passages.

1.04 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Qualifications.
   1. Identify and provide required documentation for FRL tunnel rescue personnel for all underground work shifts for work in the tunnel.
C. Training Plan and Documentation.
D. Completed MSHA Forms.
E. Rescue Notification Plan

1.05 QUALITY ASSURANCE
A. Qualifications:
   1. FRL Tunnel Rescue Personnel:
      a. Ensure each person has been employed in an underground tunnel construction project for a minimum of one year within the past five years.
      b. Ensure personnel, who are employed on the surface but work regularly underground, meet the experience requirement.

1.06 SCHEDULING
A. Availability of FRL Tunnel Rescue Personnel
   1. Provide FRL tunnel rescue personnel at all times when workers are underground.
   2. The FRL tunnel rescue requirement is applicable during all phases of underground construction operations. See Sections 31 71 19, Tunnel Excavation by Tunnel Boring Machine, and Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.
   3. Completion of the tunnel and cross passage excavation does not preclude the need for the availability of FRL tunnel rescue personnel during subsequent phases of underground construction.
   4. Provide a minimum three FRL tunnel rescuers per underground shift, who are qualified, trained, and equipped for providing emergency tunnel rescue service.
   5. FRL tunnel rescue personnel shall be available at the tunnel entrances or exits after notification of an occurrence that might require their services. Consider tunnel rescue personnel available even if performing regular work duties.
6. Detailed statement describing the proposed method of compliance with the requirements for FRL tunnel rescue.
   a. Include the names of the FRL tunnel rescue personnel in the statement.
   b. Post a copy of the statement at the tunnel entrance for the workers information.

1.07 TUNNEL RESCUE EQUIPMENT STATION
   A. Designate in advance of the start of tunneling the location of the tunnel rescue equipment station serving the tunnel construction site.
   B. Locate equipment at the tunnel construction sites to be served by the work.
   C. Tunnel rescue equipment stations are to be centralized, organized storage locations for tunnel rescue equipment designed to ensure readiness for immediate use.

1.08 MAINTENANCE
   A. Provide tunnel rescue equipment station with at least the following equipment:
      1. Twelve self-contained oxygen breathing apparatus, each with a minimum of two hours capacity (approved by MSHA and NIOSH under 42 CFR part 84, subpart H), and any necessary equipment for testing such breathing apparatus.
      2. A portable supply of liquid air, liquid oxygen, pressurized oxygen, oxygen generating or carbon dioxide absorbent chemicals, as applicable to the supplied breathing apparatus and sufficient to sustain each team member for 6 hours while using the breathing apparatus during rescue operations.
      3. One extra oxygen bottle (fully charged) for every six self-contained compressed oxygen breathing apparatus.
      4. One oxygen pump or a cascading system, compatible with the supplied breathing apparatus.
      5. Twelve permissible cap lamps and a charging rack.
      6. Two gas detectors appropriate for each type of gas which may be encountered at the tunnel(s) served.
      7. Two oxygen indicators.
      8. One portable tunnel rescue communication system (approved under 30 CFR 23) or a sound-powered communication system. Verify that the wires or cable to the communication system are of sufficient tensile strength to be used as a manual communication system. These communication systems shall be at least 1,000 feet in length.
      9. Necessary spare parts and tools for repairing the breathing apparatus and communication system.
   B. Coordinate maintenance and inspection of the tunnel rescue equipment with the SFD Tunnel Rescue Team.
      1. Review the condition of all equipment on a monthly basis.
2. Establish protocols for transition from FRL tunnel rescue to SFD Tunnel Rescue Team during emergency events.

C. Maintain tunnel rescue apparatus and equipment in a manner that ensures readiness for immediate use.

D. Verify that a person trained in the use and care of breathing apparatus inspect and test the apparatus at intervals not exceeding 30 days and certifies, by signature and date, that the inspections and tests were completed.

E. When the inspection indicates that a corrective action is necessary, make the corrective action and have the trained person record the corrective action taken.

F. Maintain the certification and the record of corrective actions at the tunnel rescue equipment station and make available to the Resident Engineer upon request.

1.09 PHYSICAL REQUIREMENTS FOR FRL TUNNEL RESCUE PERSONNEL

A. Each designated FRL tunnel rescuer shall be examined within 30 days of commencing underground site work and annually thereafter, by an occupational physician who certifies that each person is physically fit to perform tunnel rescue and recovery work for prolonged periods under strenuous conditions.

B. A minimum of two persons per underground shift shall pass the medical examination for compressed air work.

C. Personnel requiring corrective eyeglasses shall not be disqualified from providing FRL tunnel rescue services provided the eyeglasses can be worn securely within an approved facepiece.

D. Complete MSHA Form 5000-3 (certifying medical fitness) completed and signed by the examining physician for each FRL tunnel rescue person. Submit to MSHA and the Resident Engineer.

1.10 RESCUE NOTIFICATION PLAN

A. Each tunnel shall have a Rescue Notification Plan outlining the procedures to follow in notifying the on-site FRL tunnel rescue personnel and the Primary Tunnel Rescue Responder SFD Tunnel Rescue Team and the protocol for communication and responsibility during an emergency, when the SFD Tunnel Rescue Team arrives at the Site.

B. Post a copy of the Rescue Notification Plan at each tunnel entrance for the worker’s information.

1.11 TRAINING REQUIREMENTS

A. Conduct the training courses required by this Section jointly and collaboratively with and under the direction of the SFD Tunnel Rescue Team and instructors.

1. FRL tunnel rescuer designated personnel shall complete, at a minimum, an initial 20-hour course of instruction, as prescribed by MSHA’s Office of Educational Policy and Development in the use, care, and maintenance of the type of breathing apparatus which shall be used on-site.

B. Upon completion of the initial training, verify that all FRL personnel receive at least 40 hours of refresher training annually jointly and in collaboration with the SFD Tunnel
Rescue Team. This joint training shall include at least four hours each month, or for a period of eight hours every two months. Include in this training:

1. Sessions underground at least once each month.
2. The wearing and use of the breathing apparatus.
3. The use, care, capabilities, and limitations of auxiliary tunnel rescue equipment, or a different breathing apparatus.
4. Advanced tunnel rescue training and procedures, as prescribed by MSHA’s Office of Educational Policy and Development.
5. Tunnel map training and ventilation procedures.

C. Personnel shall be ineligible to serve as a FRL tunnel rescuer if more than eight hours of training is missed during 1 year, unless additional training is received to make up for the time missed.

D. Maintain a record of training for each FRL tunnel rescue person on file at the tunnel rescue equipment station for a period of 1 year.

1.12 TRAINING PLAN FOR FRL TUNNEL RESCUE PERSONNEL

A. Verify that each FRL tunnel rescuer receives no less than 20 hours of training as indicated in this Section before such person is assigned to work duties. Ensure such training is conducted in conditions that, as closely as practicable, duplicate actual underground conditions, and approximately eight hours of training shall be given at the tunnel site jointly with the SFD Tunnel Rescue Team.

B. Include the following courses in the training program for FRL tunnel rescuers not previously approved as a FRL tunnel rescuer on this Contract:

1. Self-rescue and respiratory devices:
   a. Instruction and demonstration in the use, care, and maintenance of self-rescue and respiratory devices used at the tunnel.
   b. Training in the use of self-contained self-rescue devices including complete donning procedures in which each person assumes a donning position, opens the device, activates the device, inserts the mouthpiece, or simulates this task while explaining proper insertion of the mouthpiece, and puts on the nose clip.
   c. Given before the new tunnel rescuer goes underground.

2. Entering and leaving the tunnel; transportation; communications:
   a. Instruction on the procedures in effect for entering and leaving the tunnel: The check-in and check-out system in effect at the tunnel; the procedures for riding on and in tunnel conveyances; the controls in effect for the transportation of tunnelers and materials; and the use of the tunnel communication systems, warning signals, and directional signs.

3. Introduction to the work environment:
   a. A visit and tour of the tunnel, or portions of the tunnel, which are representative of the entire tunnel.
b. The mining methods utilized at the tunnel shall be observed and explained.

4. Tunnel map:
   a. A review of the tunnel map; the escapeway system; the escape, firefighting, and emergency evacuation plans in effect at the tunnel; and the location of abandoned areas.
   b. Introduction to the methods of barricading and the locations of the barricading materials, where applicable.
   c. Use the training program for instruction on escapeways and emergency evacuation plans.

5. Ground control and ventilation plans:
   a. Introduction to and instruction on the ground control method in effect at the tunnel; and an introduction to and instruction on the ventilation plan in effect at the tunnel and the procedures for maintaining and controlling ventilation.

6. Health:
   a. Include instruction on the purpose of taking dust, noise, and other health measurements, and any health control plan in effect at the tunnel.
   b. Explain the health provisions of the WISHA and warning labels.

7. Hazard recognition:
   a. Include the recognition and avoidance of hazards present in the tunnel.

8. Electrical hazards:
   a. Recognition and avoidance of electrical hazards.

9. First aid:
   a. Instruction in first aid methods acceptable to MSHA.

10. Tunnel gases:
    a. Instruction in the detection and avoidance of hazards associated with tunnel gases.

11. Health and safety aspects of the tasks to which the new FRL tunnel rescuer will be assigned, including:
    a. Safe work procedures of such tasks.
      1) Mandatory health and safety standards pertinent to such tasks.
      2) Information about the physical and health hazards of chemicals in the tunneler’s work area.
      3) The protective measures a tunneler can take against these hazards.
4) The contents of the tunnel’s HazCom program.

C. Include within the training plan methods, such as oral, written, or practical demonstration, by which the training is to be considered successfully completed. Administer the methods for determining such completion before assigning tunnel rescue personnel to actual work duties.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 FIELD QUALITY CONTROL

A. Provide FRL tunnel rescue personnel that meet the requirements of this Section, and make them available for service prior to performing any work in a tunnel.

B. Supplement the initial training requirements specified above by assembling the FRL tunnel rescue personnel jointly with the SFD Tunnel Rescue Team as a group on a monthly basis and reviewing access constraints, location of emergency equipment, availability of personal protective equipment, and other necessary information. Additional assembly times to include:

   1. Prior to launching and relaunching the TBM.
   2. Prior to beginning cross passage construction.

C. Coordinate all work and responsibilities of the FRL tunnel rescue personnel with the Site Health and Safety Officer.

END OF SECTION
1.01 SUMMARY

A. This Section specifies requirements for tail void grouting during tunneling including quality control and proof grouting to ensure continuous contact between the extrados of the precast concrete tunnel lining (rings) and the surrounding soil.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete.
2. Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.
3. Section 31 74 16, Precast Concrete Tunnel Lining.
4. Section 01 74 01, Excavation Spoils and Muck Disposal.

1.02 REFERENCES

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

2. ASTM C150 Standard Specification for Portland Cement
3. ASTM C494 Standard Specification for Chemical Admixtures for Concrete
4. ASTM C827 Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens of Cementitious Mixtures

1.03 DEFINITIONS

A. Extrados: Exterior circumferential surface of the precast segmental lining system.

B. Grout Recess: Optional circular void cast in precast concrete segment to facilitate proof grouting.

C. Inbye: Reference to a position closer to the face.

D. Intrados: Interior circumferential surface of the precast segmental lining system.

E. Lost Ground Void: Space between the outside of the precast concrete segments and the surrounding soils, which may exist in addition to Tail Voids, due to loss of ground.

F. Lost Ground: Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

G. Outbye: Reference to a position closer to the tunnel portal.
H. **Proof Grout:** Cement-based grout injected into the space between the precast segmental lining and the tail void grout to fill any voids and ensure continuous contact of the ring with the surrounding soil.

I. **Required Support Pressure:** Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

J. **Tail Void:** Space between the extrados of the precast concrete segmental lining and the surrounding soil behind the tail shield formed by overcut of TBM cutterhead, thickness of the TBM shield, and clearance between the intrados of the shield and the extrados of the segments.

K. **Tail Void Grout:** Material used to fill the Tail Void.

### 1.04 SYSTEM DESCRIPTION

A. **General:** Design grout mix with appropriate properties to provide intended functions, as defined herein.

B. **Use granular cement-based, a two-component grout type, or other types of grout that meet the specified requirements herein.**

C. **Provide grouting materials with adequate flow properties to enable complete filling of tail void gap simultaneously with TBM advance.**

D. **Provide grouting material with properties adapted to the grout injection process and encountered ground conditions.**

E. **Prevent segregation of grouting material during mixing, pumping, and injection.**

F. **Provide Tail Void Grout with adequate setting characteristics, especially sufficient initial compressive strength, to guarantee bedding of the segmental lining and to prevent uplift and deformations of it due to loading.**

G. **Compressive strength:**
   1. Minimum 15 pounds per square inch (psi) in 1 hour.
   2. Minimum 250 pounds per square inch (psi) in 28 days.
   3. Maximum 400 pounds per square inch (psi) in 28 days.

### 1.05 SUBMITTALS

A. **Procedures:** Section 01 33 00, Submittal Procedures.

B. **Qualifications for Grouting Manager.**

C. **Mix Designs:**
   1. For each proposed mix of Tail Void Grout provide:
      a. **Type and Characteristics**
      b. **Proportions of each ingredient**
      c. **Test results from trial mixing and testing.**
   2. **Lost Ground Void grout.**
D. Product Data:

1. Manufacturer's product data sheets including:
   a. Mixing, handling, storage, and waste disposal requirements.
   b. Source of supply for each grout ingredient.

2. For each type and source of material:
   a. Cement.
   b. Grout components, if not cement-based grout.
   c. Admixtures: Documentation showing that the proposed admixtures have a history of demonstrable satisfactory performance and are compatible with adjacent materials.

E. Working Drawings and Methods Statements:

1. Layout and description of grout mixing, transport, and injection facilities including:
   a. Supply equipment.
   b. Agitators or holding tanks.
   c. Batching and mixing units.
   d. Grout cars.
   e. Pumps.
   f. Grout delivery piping and manifolds.
   g. Calculations of grout pressure range along the tunnel alignment.
   h. Hookup details including valves and gauges.

2. Means and methods for:
   a. Proportioning and mixing of grout.
   b. Transport of grout.
   c. Injection of grout.
   d. Grouting pressures along the alignment.
   e. Measuring grout pressure, quantity, and injection rate.
   f. Maintaining grout pressure within specified limits.
   g. Establishing basis and threshold values for modifying grout mixes.
   h. Minimizing washout and migration of grout into the excavation chamber.
   i. Performing test borings to determine thickness and properties of injected tail void grout.
   j. Injection of proof grout.
k. Calibration of gauges and meters to be used in grouting operations.
l. Collecting and disposing of excess material.
m. Collecting and disposing of water resulting from grouting operations.

3. Integrate means and methods for performing this work with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 74 16, Precast Concrete Tunnel Lining as related to tunnel excavation and installation of the precast concrete segments.

F. Quality Control:

1. Certifications.

2. Quality Control Plans:
   a. Methods for demonstrating that grout mix meets design criteria.
   b. Methods for assuring uninterrupted grouting at pressures within specified limits.
   c. Methods for demonstrating that injected grout filled completely the tail void gap.
   d. Methods for containing and disposing of excess grout and cleaning of equipment.
   e. Methods for preventing grout migration into the cutterhead from behind the tunnel shield.
   f. Methods for the injection of proof grout.

3. Daily Records:
   a. Shift report, regardless of actual progress, and submitted no later than the beginning of the following working day. Include:
      1) Number and type of equipment used.
      2) List of idle or inoperative equipment and reason for downtime.
      3) Grout injection records for each segment:
         a) Mix type and batch number.
         b) Detailed grout injection records, broken down for each outlet by injected quantity, injection pressure and pumping rate.

4. Weekly Records: Results of testing on grout samples taken during production grouting.

5. Notifications: Immediately if Warning Level or Critical Level specified herein is reached.

6. Tests: Results of trial mixes and tests specified herein.

7. Proof grouting reports as specified herein.
1.06 QUALITY ASSURANCE

A. Qualifications:

1. Grouting Manager: A minimum of three years of related work experience on similar projects to manage the grouting program by designing, testing, and overseeing the injection of grout mixes of the type required through the TBM tail shield injection lines.

B. Certifications:

1. Certificates of compliance for materials listed under Part 2 of this Section.
2. Calibration certificates for gauges and meters to be used in grouting operations.

C. Testing:

1. To demonstrate conformance with the specified requirements as indicated herein, provide the services of an Independent Testing Laboratory (ITL).
2. Perform preliminary grout suitability tests before start of tunneling operations including but not limited to: bleed water, gel strength and pumpability tests.
3. Trial mix: Find and define a suitable grout by testing at least, but not limited to, the unconfined compressive strength at 1 hour and 28 days, as well as characteristics of grout to completely fill annular space. A minimum of 6 tests should be performed on each trial mix.
4. Perform tests during production grouting for unconfined compressive strength.
   a. Test a minimum of 4 samples taken from daily production every 250 feet of tunnel length or once a week, whatever comes first, to verify the grout mix.
   b. Collect grout samples at the injection point.
5. Confirm that Tail Void Grout has been placed and cured by drilling through Segment Rings and inspecting the condition of Tail Void Grout:
   a. Drill through segment and perform Proof Grouting as required through the first 100 rings of precast concrete segments for each of the tunnels.
   b. Drill and perform Proof Grouting as required through a segment ring at a maximum interval of 250 feet in each of the tunnels.
   c. Drill and perform Proof Grouting as requested by the Resident Engineer in the area surrounding any ring which requires Proof Grouting due to existence of un-grouted Tail Void.

PART 2 - PRODUCTS

2.01 MATERIALS

A. In accordance with Section 03 05 15, Portland Cement Concrete, for cement-based grouts, except as modified herein.

B. For non-cement based grouts: As required by manufacturers to meet requirements specified herein.
C. Admixtures:
   2. Anti-washout agent: in accordance with Contractor as required.
   3. Admixtures and fluidifiers that promote steel corrosion are not acceptable.
   4. Use admixtures compatible with proposed mixing water and contain no more than 0.1 percent chloride ion by weight of portland cement.

D. Non-Shrink Grout: ASTM C827.

2.02 EQUIPMENT
A. Grouting:
   1. General:
      a. In accordance to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.
      b. Volumetric Measuring Device: Accurate to 1.5 gallons.
      c. Provide scale or measuring device to measure continuously the weight of the grout reservoir or the height difference of the grout in the car.
      d. Pressure gages: Accurate to plus or minus 1 pound per square inch (psi) over allowable grouting pressure range.
      e. Interlink grouting system to the TBM advance.
      f. Provide pressure and volume measurements for each injection line and weight measurements, all continuously to the TBM display and TBM Data Monitoring system.
      g. Provide appropriate grout valves for proof grouting.
      h. Provide coring drill and bits for coring into tail void and retrieving core samples.
   2. Pumps:
      a. Use pumps suitable for pumping grout.
      b. Each piston of a double piston pump or each hose pump shall feed no more than one injection line to guarantee continuous grout injection.
      c. Equip with a water or bentonite connection to facilitate flushing the system.
      d. Provide an emergency cutout in case of excessive grouting pressure.
      e. Provide appropriate proof grouting pumping equipment and hoses.
   3. Provide batching, mixing, and agitating equipment capable of thoroughly mixing components of Tail Void Grout, for anticipated volumes required to continuously and completely fill the Tail Void during each shove of the TBM.
B. Maintain an adequate supply of spare parts and equipment to support uninterrupted grouting operations.

C. Proof Grouting Equipment:
   1. General: Provide for continuous circulation of grout within the system.
   2. Mixer:
      a. Use a high-speed colloidal-type mixer with a tangential return flow from the mixer pump capable of providing a homogenized mix.
      b. Size to ensure an uninterrupted supply of grout to the pump.
      c. Provide with a means of accurately measuring and metering grout ingredients, including modifying the water/cement ratio.
   3. Agitator:
      a. Equip with:
         1) Baffles to induce turbulence.
         2) Rotating paddles to assure thorough mixing of the grout prior to and during injection.
   4. Pumps:
      a. Use an appropriate grout pump for the type volume and pressures specified
      b. Equip with a water connection to facilitate flushing the system.
      c. Equip with a pressure gage.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Perform tail void grouting as an integral part of the requirements of Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 74 16, Precast Concrete Tunnel Lining.

B. Preparation:
   1. Prepare calculations to determine required grouting pressure range along the tunnel alignment.
      a. Incorporate Required Support Pressure calculations in accordance with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine and Section 31 74 16, Precast Concrete Tunnel Lining.
      b. Maintain calculations, in files on Site, and make available upon request of the Resident Engineer.
   2. Adapt maximum grouting pressure to meet the capacity of the segment lining and the capacity of the sealing systems.

C. Injection:
1. Performed through grout lines integrated in the shield tail such that complete filling and pressurization of the void is simultaneous with TBM advance.

2. If the main grout line is blocked during grouting, provide the capability to switch over to the spare line to assure continuous filling of the Tail Void. Clean blocked grout lines prior to advancement for subsequent ring.

3. Tail void grouting through precast concrete segments is not permitted.

4. Perform grouting uniformly through all grout lines.

5. Regulate the pressure and monitor volume injected at each grout injection line.

6. Ensure minimum effective grouting pressure at outlets which equals the required support pressure taking into account friction losses and other practical requirements to ensure complete filling of the void.

D. Adapt material properties of grout material during tunneling operation to guarantee required bedding of segmental lining.

E. Do not disturb, displace, or distort the initial lining while performing tail void grouting.

3.02 FIELD QUALITY CONTROL

A. Gages and Meters:

1. Test field gages and meters in the presence of the Resident Engineer no less often than weekly using master gages and meters.

2. Verify accuracy of master gages and meters through the use of an Independent Testing Laboratory no less frequently than every two months.

B. Proof Grouting and Remedial Work: Perform proof grout injection as specified below in case of incomplete backfill of ring gap by tail void grouting:

1. Mix Designs: Use a basic grout design of neat cement mix with water, with a cement ratio in the range by weight of 0.5:1 to 0.6:1. Use a mix compatible with the Tail Void Grout mix design.

2. Drilling equipment: Use a concrete coring drill with appropriately dimensioned coring bit for coring segment concrete and sampling tail void grout. Coordinate location of core with permissible drilling locations identified on segments.

3. Grout recess: If grout recesses in precast segments are used, core out remaining portion of precast segment with appropriately dimensioned coring bit.

4. Other equipment:
   a. Packers: Capable of sealing grout receptacles or holes without leakage when grouting at the maximum specified pressure.
   b. Hoses and piping:
      1) Provide a manifold system of valves and pressure gauges in the line at the collar of the hole to permit accurate control and monitoring of grouting pressure, bleeding, and regulation of flow.
      2) Size: 1-1/2 inches nominal diameter or sized to fit the grout receptacles or holes in segments.
c. Pressure gages: Accurate to plus or minus 2 pounds per square inch (psi) through the allowable grouting pressure range.

5. Execution general:
   a. Perform drilling and coring on a dedicated platform at least 50 feet outbye of the TBM tail shield.
   b. Perform drilling and grouting through the plastic threaded lifting insert or shear pocket where no lifting insert is present nearest to the crown of the ring. When such a connection is not practicable, perform grouting through a packer placed in a hole cored through the segmental ring.
   c. When a void is discovered, drill out the lower adjacent lifting insert until no voids are found. Then proceed with grouting from lower holes to higher holes except where otherwise indicated.
   d. Grout that has not been placed within two hours of the time of initial mixing, spilled and cured grout and other grouting waste shall be disposed of in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.

6. Preparation:
   a. Core out lifting inserts or remainder of grout recesses where grouting is to be performed and venting and communication may occur.
   b. Drill out each grout hole from the intrados of the segments until soil is contacted but not greater than 18 inches measured from the intrados.
   c. If non-cohesive saturated soils are detected, carry out core drilling through a grout packer equipped with a valve and back-flow preventer as necessary.
   d. Flush the hole with water except where a back-flow preventer is being used.

7. Placement:
   a. Do not pump grout into more than one hole simultaneously.
   b. Fit each hole drilled with an appropriate packer and valve.
   c. Where multiple holes have been drilled, relieve air and water through an open hole closer to the crown than the one being injected.
   d. Do not close any open un-grouted hole if communication is noted until:
      1) Grout of the same consistency as that being injected issues forth.
      2) Grout issues forth at the volume rate being injected.
   e. If no communication is observed grout each hole to refusal: when the total amount of grout injected into a hole is less than four gallons as measured over a continuous two-minute period at the maximum specified pressure.
   f. Grout the hole closest to the crown to refusal as described above.
g. Remove grout valves after the grout has reached initial set and clean out the hole to a minimum depth for which the grout plug can be inserted.

h. Install grout plugs at grout ports in the segmental lining and tighten.

i. Repair any holes drilled through the segmental lining after grouting in accordance with Section 31 74 16, Precast Concrete Tunnel Lining.

C. Monitoring

1. Monitor actual volume of Tail Void Grout placed for each ring, and compare with theoretical volume associated with Tail Void.

2. Monitor grouting pressures required to inject Tail Void Grout.

3. When the Warning Levels specified in Table 1 below are reached:
   a. Notify Resident Engineer immediately.
   b. Continue to inject grout until Tail Void is completely filled, or allowable injection pressure is exceeded.
   c. Adjust work routine to ensure adequate grout quantities are injected into the tail void by modifying grout mix, injection pressures, quantities of admixtures, or other factors.
   d. Report effects of work routine modifications to Resident Engineer.

4. When the Critical Levels specified in Table 1 below are reached:
   a. Notify Resident Engineer immediately.
   b. Stop TBM advance provided that this can be done under safe and secure conditions. Continue to inject grout until Tail Void is completely filled, or allowable injection pressure is exceeded.
   c. Restart tunneling procedure by agreement of the Resident Engineer.
   d. Report effects of work routine modifications to the Resident Engineer.

<table>
<thead>
<tr>
<th>WARNING LEVEL</th>
<th>CRITICAL LEVEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grout volume less than or equal to 90 percent of total theoretical volume per ring at Required Support Pressure; or Grout volume greater than or equal to 150 percent of total theoretical volume per ring at or below the Required Support Pressure</td>
<td>Grout volume less than or equal to 90 percent of total theoretical volume for the third consecutive ring; or Grout volume greater than or equal to 150 percent of theoretical volume for the third consecutive ring.</td>
</tr>
</tbody>
</table>

5. Fill Lost Ground Voids with approved sand and cement mix.

3.03 CLEANING

A. Minimize waste and losses.
B. Collect and dispose of excess materials resulting from grouting operations in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.

C. Do not allow excess materials to be mixed with other water in the tunnel.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section specifies requirements for bolted, gasketed, precast concrete segments for the final tunnel lining.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 05 15, Portland Cement Concrete.
2. Section 03 20 00, Concrete Reinforcing.
3. Section 03 24 00, Fibrous Reinforcing.
4. Section 31 50 00, Excavation Support and Protection.
5. Section 31 66 17, Slurry Diaphragm Walls.
7. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.
8. Section 31 73 23, Tail Void Grouting.

1.02 REFERENCES

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

1. American Concrete Institute (ACI)
   a. ACI 318 Building Code Requirements for Structural Concrete
   b. ACI 347 Guide to Formwork for Concrete Structures
   c. ACI 517.2 Accelerated Curing of Concrete at Atmospheric Pressure
   d. ACI 533 Guide for Pre-cast Concrete Wall Panels

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   b. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   c. ASTM A108 Standard Specification for Finished Steel Bar, Carbon and Alloy, Cold Finished
d. ASTM A184 Standard Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement

e. ASTM A185 Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

f. ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, 60,000 pounds per square inch (psi) Tensile Strength

g. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 kilopounds per square inch (ksi) Minimum Tensile Strength

h. ASTM A490 Standard Specification for Structural Bolts, Alloy Steel, Heat Treated, 150 kilopounds per square inch (ksi) Minimum Tensile Strength

i. ASTM A706 Standard Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement

j. ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens


l. ASTM D395 Standard Test Methods for Rubber Property - Compression Set

m. ASTM D412 Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers –Tension

n. ASTM D573 Standard Test Method for Rubber – Deterioration in an Air Oven

o. ASTM D1149 Standard Test Method for Rubber Deterioration Cracking in an Ozone controlled Environment

p. ASTM D2240 Standard Test Method for Rubber Property - Durometer Hardness

q. ASTM E329 Standard Specification for Agencies Engaged in Construction Inspection and/or testing

1.03 DEFINITIONS

A. Circumferential Joints: Joints between adjacent segment rings, perpendicular to the direction of the tunnel.

B. Gap: Distance between segment load-bearing surfaces at joints, dependent in part on the amount of gasket compression and packing thickness.

C. Segmental Lining: Bolted, gasketed, precast concrete segments (also called Precast Concrete Segments) erected as a ring within the TBM tail shield and designed to resist short and long term ground and hydrostatic loads. The segmental lining is also capable of resisting thrusts from the TBM as the tunnel excavation is performed.

D. Groundwater Seepage: Inflow into the tunnel through the tunnel lining.

E. Longitudinal Joints: Joints between adjacent segments, parallel to the direction of the tunnel.
F. Compression Packing: Load-distributing elements cut to the geometries of the longitudinal or circumferential segment joints in which they are placed. The compression packing distributes compressive stresses across the segment joint without affecting the ability of the segment gasket to withstand anticipated hydrostatic pressures.

1.04 SYSTEM DESCRIPTION

A. General:

1. Minimum design of the segmental lining for rebar reinforcement is given in the specifications and as indicated on the Contract Drawings. Augment the minimum design to handle construction loading, as specified herein.

2. Base design on ACI 318 and [_____] Design Criteria Manual, as necessary.

3. At a minimum, provide the following:
   a. Segment thickness: 10 inches.
   b. Concrete compressive strength at 28 days:
      1) Class 6000B in accordance with Section 03 05 15, Portland Cement Concrete.
   c. Segments with steel bar reinforcement:
      1) Minimum cover: As indicated on the Contract Drawings.
      2) Minimum steel reinforcement ratio: As indicated on the Contract Drawings, assuming 60,000 psi yield strength for reinforcement.
      3) Minimum bursting steel reinforcement at longitudinal joints: As indicated on the Contract Drawings, assuming 60,000 psi yield strength for reinforcement.
   d. Fire protection requirements: Polypropylene Fibers, per Section 03 24 00, Fibrous Reinforcing.

4. A minimum structural design for the segments is shown on the Contract Drawings, as well as in these specifications. Augment or modify this design as necessary to meet anticipated means and methods, but modified segment designs shall meet the following requirements:
   a. General design criteria: Per requirements of the [_____] Design Criteria Manual (DCM), Section 8.3.1, referenced in Section 01 42 00, References, as well as ACI 318.
   b. Design ground and hydrostatic loads: Design segments at least for the following scenarios, in terms of depth of cover and groundwater levels:
      1) [_____]
   c. Design ground parameters: In accordance with conditions in the Geotechnical Baseline Report (GBR).
   d. Design earthquake loads: In accordance with requirements of the DCM, Section 8A, with particular focus on Section 8A.6.1.

5. Stagger joints so that longitudinal joints do not align with longitudinal joints in adjacent segment rings.
6. Provide a continuous gasket groove around all joint faces of the segments of a width necessary to accommodate the required gasket with the minimum Contractor-determined clearances, or minimum clearances between:

a. Segment extrados and the outer edge of the gasket groove to prevent spalling of the concrete due to required gasket line loads.

b. Joint compression packing and the inside edge of the gasket groove to prevent damage to the gasket when the packing is compressed while maintaining maximum ¼-inch eccentricity of the packing with respect to the centerline of the segment joint.

c. Provide chamfers for tapered longitudinal joints to reduce stress concentrations as necessary to comply with specified requirements.

7. Design segments to support temporary loading due to TBM propulsion, grout pressures, loads due to handling, stacking, demolding, and installation, consistent with selected means and methods.

8. Coordinate design of segments with procedures for constructing cross-passages, in accordance with Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.

B. Gasket:

1. Capable of handling no less than 200 percent (denotes factor of safety = 2.0) of the higher of:

   a. The maximum tail void grouting pressure determined by the Contractor to avoid damage to the precast concrete segments; or

   b. A maximum water pressure of 40 psi above atmospheric.

2. Coordinate design of the gasket system with the following items to achieve the specified performance for the anticipated range of gap widths:

   a. Gasket properties;

   b. Gasket groove depth and geometry;

   c. Anticipated compression packing thickness, if used;

3. Select and configure the gasket and gasket groove geometry to be capable of resisting extrusion into the joint gap due to tail void grout and hydrostatic pressures.

4. Capable of sealing against the maximum pressure when subjected to maximum offsets based upon erection tolerances.

C. Mechanical Joint Connector Systems:

1. Design bolted, dowelled, or other positively interlocking mechanical connections between segment panels. Connect longitudinal joints by bolts only.

2. Provide a minimum of two connections at each joint face for each segment except at circumferential joints for key taper segments, which may utilize a single connection.

3. Design connections to maintain adjacent gaskets sufficiently compressed to perform in accordance with specified requirements.
4. Design connections for all anticipated installation conditions, including loss of TBM thrust ram pressure.

D. Compression Packing:

1. Capable of transferring anticipated design loads across longitudinal or circumferential joints while maintaining at least half of original thickness. Account for given fabrication and installation tolerances in design.

2. Maintain 1/2-inch clearance from segment grooves and edges.

E. Threaded Plastic Inserts:

1. Capable of proof grouting through inserts.

2. Capable of being sealed to same design pressures as gasket using a plug or cap.

3. If used for transportation, handling and installation of segments, design for all anticipated loading conditions with a minimum factor of safety of 2.

F. Insert Drilling Location Indicators:

1. Provide minimum number of indicators as indicated on the Contract Drawings.

2. Provide a minimum of 1.2 inches of clearance between indicator and nearest reinforcement.

G. Groundwater Seepage:

1. Behind the TBM trailing gear after segment erection and tail void grouting:
   a. Total inflow from each tunnel: Less than 10 gallons per minute (gpm).
   b. Maximum inflow at a single point: Less than 0.1 gpm.
   c. No active drips or seeps above springline of the tunnel.

H. Fabrication Tolerances:

1. Fabrication: Cast with such accuracy and uniformity of dimensions that segment panels of the same type are interchangeable from segment ring to segment ring.

2. Reinforcement placement: Cover between reinforcement and forms of – 0 inch, + 1/2 inch.

3. As indicated on the Contract Drawings.

I. Erection Tolerances:

1. Inside diameter of the erected ring: +/- 0.5 percent of the inside diameter.

2. Limit steps on the internal surface between abutting segments to no greater than 3/8 inch.

3. Limit the roll of one ring relative to the adjacent ring to not exceed 1/8 inch.

1.05 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Manufacturer’s product data and performance sheets, including recommendations and requirements for handling, storage, and protection for the following:

1. Gasket materials:
   a. Three samples each of gaskets, plus a sample of the gasket adhesive.
   b. Gasket information including test data demonstrating ability to meet specified design and performance criteria.

2. Segment bolts:
   a. Three samples of type proposed for use.
   b. Bolt information, including test data or manufacturer’s certification of compliance with design strengths required.

3. Segment dowel:
   a. Three samples of type proposed for use.
   b. Manufacturer’s information, including test data or manufacturer’s certification of compliance with design strengths required.

4. Grout hole/lifting sockets:
   a. Three samples of type proposed for use.
   b. Manufacturer’s information, including test data or manufacturer’s certification of compliance with design strengths required.

5. Compression Packing material: Three samples of type proposed for use.

6. Polypropylene fiber reinforcement: In accordance with Section 03 24 00, Fibrous Reinforcing.

C. Shop Drawings:

1. Dimensioned details of precast concrete segment geometries and features comprising:
   a. Layout and size of each segment.
   b. Number of segments per ring.
   c. Taper configurations.
   d. Key configuration.
   e. Concrete grade and type.
   f. Reinforcement.
   g. Gaskets and gasket grooves.
   h. Joint details.
   i. Compression packing.
   j. Inserts and insert drilling location indicators.
k. Mechanical joint connections.

l. Segment identification information.

2. Details for construction of each type of mold used to cast the precast concrete segments. Include for each type of segment:
   a. The number of molds to be fabricated.
   b. Details for securing embedded items in place during casting.
   c. Form geometry and dimensions.
   d. Fabrication Tolerance for:
      1) Circumferential length
      2) Width
      3) Flatness of segment joint face
      4) Width of gasket groove
      5) Depth of gasket groove
      6) Mismatch of gasket groove at corners
      7) Warping
      8) Connector locations

D. Working Drawings and Method Statements:
   1. Physical description and properties of design elements, including details, dimensions, supporting design calculations demonstrating compliance with specified performance criteria, and list of design criteria. Provide calculations that are stamped, dated and signed by the Segment Designer.
   2. Details for compression packing incorporated into the longitudinal and circumferential joint surfaces between segments, including type of material, thickness, compressibility, and calculations and test results demonstrating compliance with minimum design criteria specified herein.
   3. Details of segment production, comprising:
      a. Name, address, and contact information for the Segment Manufacturer.
      b. Location of casting and storage yards.
      c. Means and methods for:
         1) Batching concrete with and without fibrous reinforcement.
         2) Casting, curing, and stripping/demolding segments.
         3) Affixing segment gaskets and compression packing.
         4) Handling and storing segments.
      d. Segment production schedule.
4. Refer to Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine, for submittal requirements for transporting segments into the tunnel, erection and fastening of segments.

5. Refer to Section 31 73 23, Tail Void Grouting, for submittal requirements for placing tail void grout.

6. Refer to Section 31 50 00, Excavation Support and Protection, and Section 31 66 17, Slurry Diaphragm Walls, for submittal requirements for integrating the segmental lining with other initial support systems at the stations.

7. Refer to Section 31 71 23, Tunnel Excavation by Sequential Excavation Methods, for submittal requirements for integrating the segmental lining with initial support systems at the cross-passages.

8. Segment Repair: Detailed procedure for process of repairing segments during fabrication, during installation, and after installation in the tunnel.

E. Mix Designs: In accordance with Section 03 05 15, Portland Cement Concrete, and as specified herein.

F. Qualifications:
   1. Segment Manufacturer.
   2. Segment Designer.

G. Certifications:
   2. That precast concrete segments meet minimum design and performance criteria specified.
   3. Separately by Contractor and manufacturer that precast concrete segments are capable of supporting storage, transportation, handling, erection, and TBM thrust loads.
   4. By Contractor that the circularity tolerance specified is consistent with the Contractor’s proposed segment configuration and geometry.

H. Quality Control Plans:
   1. Segment Casting:
      a. Methods for measuring and assuring that tolerances are met with due consideration for thermal, moisture, and ambient temperature influences.
      b. Methods for testing and sampling to verify minimum required compressive strength before stripping, all in accordance with Section 03 05 15, Portland Cement Concrete.
      c. Methods for demolding segments to prevent spalling and other forms of damage to gasket grooves and segment edges.
      d. Methods for controlling shrinkage and temperature cracking.
      e. Methods for assuring even distribution of fibers in concrete mixes during placement in molds.
f. Record keeping and procedures for resolving quality defects.

g. Methods for assuring that segment production does not impact tunnel excavation.

2. Segment Protection: Methods for protecting segments and appurtenances from damage while handling, transporting, storing, and installing.

3. Segment ring mockups assuring compliance with indicated tolerances and segment interchangeability requirements.

I. Records:

1. Fabrication
   a. Daily and weekly summaries of segments fabricated, including types of segments, mixes used, curing details, strength testing results, storage location, and other information specified herein.
   b. Weekly summary of segments transported to the construction sites.
   c. Weekly summary of damaged segments at the fabrication plant, including types of repairs if used, and whether repairs were successful.
   d. Results of segment and mold dimension checks.
   e. Results of mock ups and ring fit-ups.
   f. Source Quality Control testing results.

2. Installation: In accordance with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

1.06 QUALITY ASSURANCE

A. Qualifications:

1. Segment Manufacturer:
   a. Experience with manufacturing bolted, gasketed, precast concrete segments of similar dimensions and tolerances to those specified.
   b. Required to have been in business for at least 5 years and provided precision tunnel rings for two projects comparable to the work of this Contract.
   c. Comparable work includes bolted, gasketed, precast concrete tunnel lining segments installed as tunnel lining below the groundwater table.

2. Segment Designer: Licensed Structural Engineer registered in the State of Washington with a minimum of five years of recent experience in underground construction and in the design of bolted, gasketed, precast concrete segments below the groundwater table.

B. Testing:

1. To demonstrate conformance with the specified requirements as indicated herein, provide the services of an Independent Testing Laboratory (ITL), in accordance with Section 01 45 00, Quality Control.
C. Acceptance Criteria:

1. Adequacy of Structural Design: Calculations demonstrating that the segments meet the criteria indicated, in conjunction with:
   a. Gasket line loads developed at the expected gaps.
   b. Means and methods to achieve the Groundwater Seepage criteria limits under the given hydrostatic and tail void grouting pressures, adjusted by the factor of safety specified herein.
   c. Temporary construction loads, from handling, transporting, erecting, and TBM jacking, with and without full benefit of tail void grouting, as well as other loads as may be applied during construction of the segmental tunnel lining.

2. Casting of segments to:
   a. Individual panel and collective ring tolerances as indicated.
   b. Meet or surpass all design criteria.

3. Erection of segments:
   a. Meet or surpass specified Groundwater Seepage criteria.
   b. Meet tolerances specified or indicated.

D. Prefabrication Conference

1. Schedule and conduct a prefabrication conference between the Resident Engineer and the Segment Manufacturer within 30 days of the intended start of fabrication of the segments.

2. Discuss issues such as record keeping, testing, inspection logistics, quality assurance and control, and other fabrication-related matters.

1.07 PRODUCT DELIVERY, STORAGE AND HANDLING

A. Transport the required amounts of tapered segment panels in complete ring assemblies and as required to maintain a sufficient number of segment rings available to the tunneling operation.

B. Protect gaskets and compression packings from direct exposure to sunlight and weather as needed based on manufacturer’s recommendation. Replace gaskets and compression packings that show signs of deterioration.

C. Transport, store, and handle segments, avoiding damage to surfaces, edges and corners, and avoiding the development of stresses exceeding the capacity of the segment.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Reinforcing Steel:
   1. Welded wire fabric: In accordance with Section 03 20 00, Concrete Reinforcing.
   2. Bar reinforcement:
a. In accordance with Section 03 20 00, Concrete Reinforcing.
b. For welded bars for ladder mats at longitudinal joints: ASTM A706.

B. Mechanical Joint Connector Systems:

1. Structural bolts, nuts and washers:
   a. ASTM A325 or ASTM A490.
   b. Minimum bolt size: 3/4-inch diameter.
   c. Hot-dipped galvanized.
   d. Curved bolt systems prohibited.

2. Steel dowels for circumferential joints:
   a. ASTM A108 Grade 1018.
   b. Minimum diameter: 3/4-inch.
   c. Hot-dipped galvanized.

3. Plastic dowels for circumferential joints:
   a. Fiber reinforced engineered thermoplastic.
   b. Ring formed pliable elastic surfaces.
   c. Minimum diameter: 2.5-inches.
   d. Maximum diameter: One-third thickness of segment.
   e. Minimum length: 7 inches.

C. Concrete: Section 03 05 15, Portland Cement Concrete, and as specified herein.

D. Polypropylene Fibers: Section 03 24 00, Fibrous Reinforcing.

E. Gaskets:

1. Continuous over joint surfaces and of uniform gasket thickness along the entire length of mating surfaces, with vulcanized corners.

2. Material free of imperfections including: Voids, blisters, inclusions, flow marks, porosity, and pitting.

3. Of such durability that residual contact pressure between the gasket surfaces is capable of resisting the design hydrostatic head specified herein, as well as environmental conditions indicated in the GBR continuously over the 100-year period following erection.

4. Made of dense elastomeric synthetic rubber.


6. Tensile Strength: ASTM D412, greater than 1,700 psi.

7. Elongation: ASTM D412, greater than 300 percent.
8. Compression Set: ASTM D395, Method B:
   a. Short-Term – Less than 20 percent compression after 25 percent compression at 160 degrees F for 22 hours.
   b. Long-Term – Less than 20 percent compression after 50 percent vertical compression after 70 hours at 212 degrees F.

9. Ozone Resistance: ASTM D1149, by method described in ASTM D518, Procedure A, with following stipulation:
   a. No surface cracking of untensioned specimen (zero percent elongation) when immersed in a 200 parts per hundred million ozone solution for 100 hours at room temperature and 55 percent humidity.

10. Water-tightness: Provide gaskets that meet the Groundwater Seepage criteria under the conditions specified herein.

11. Fire rating: Use a concrete test rig to demonstrate that gaskets will be unaffected by fire. Install gaskets in grooves in concrete blocks in a manner consistent with conditions in the tunnel, with a gap of 1/8-inch. Via a burner, apply a temperature of 1450 degrees F at the intrados side of the blocks for a period of 30 minutes. Set the distance between the intrados and the gaskets to be consistent with the conditions within the tunnel. Measure the temperature at the gasket, and demonstrate that less than three-quarters of the width of the gasket profile is damaged by the applied heat. Certification by the manufacturer or past test results will be accepted in lieu of specific fire rating testing.

12. Aging: ASTM D573, 70 hours at 210 degrees F. Changes in material properties shall comply with the following parameters:
   a. Hardness: Less than 6 units increase.
   b. Tensile Strength: Less than 15 percent decrease.
   c. Ultimate Elongation: Less than 30 percent decrease.

13. Stress Relaxation: Remaining stress greater than 60 percent of original stress after 100 years, based upon accelerated testing and engineering analysis.

F. Gasket and Compression Packing Primers and Adhesives: As recommended by packing and gasket manufacturers.

G. Compression Packing Material:
   1. Marine grade plywood, composite material, or other approved material. Bituminous fiberboard is prohibited.
   2. Maximum thickness of 1/4 inch.

H. Foam Strips: Compressible material capable of preventing grout from entering joints between segments.

I. Segment Repair Materials: In accordance with Manufacturer’s recommendations, and compatible with concrete mix design.

J. Grout Insert:
   1. Plastic:
2.02 FABRICATION

A. Utilize molds fabricated from steel in accordance with ACI 347.

B. Cast concrete in accordance with Section 03 05 15, Portland Cement Concrete, and in a controlled environment protected against rain, dust, and direct sunlight.

C. Place reinforcing steel in accordance with Section 03 20 00, Concrete Reinforcing.

D. Provide reinforcement spacers as specified in Section 03 20 00, Concrete Reinforcing.

E. Place fibrous reinforcing in accordance with Section 03 24 00, Fibrous Reinforcing.

F. Provide hard steel trowel finish or similar to the extrados surface.

G. Cure segments and protect during storage in accordance with ACI 533 and ACI 517.2R.

H. If steam curing is used:

1. After the segments are cast and attained preset time, place the segment forms in an enclosure or chamber large enough to allow complete circulation of steam.

2. Do not remove segments from forms until the required stripping strength is attained, as determined by test cylinders.

3. Provide enclosure or chamber ambient temperature that does not exceed 100 degrees F for the first two hours of curing; maintain temperature between 90 degrees F to 150 degrees F until the required stripping strength is attained. Continuously monitor temperatures during curing.

4. Control cooling rate to limit temperature differential to avoid thermal cracking.

5. Apply an approved curing compound on all surfaces immediately after removal of segments from steam curing.

I. Segment Identification:

1. Cast the segment type, type of taper, and mold identification directly on the segment intrados.

2. Paint the casting date adjacent to the above-cast information.

J. Segment alignment: Cast a marker into the intrados of each segment to assist in their alignment.
K. Identify locations where segments can be drilled without interfering with segment reinforcement, as indicated on the Contract Drawings, for use in attaching appurtenances to the lining.

2.03 SOURCE QUALITY CONTROL

A. Segment and Mold Dimension Checks:

1. Check mold dimensions versus tolerances for each mold prior to beginning production. Thereafter, as a minimum, check mold dimensions once for every 200 segments cast.

2. Verify that the first segment cast from any mold meets required tolerances. Thereafter, as a minimum, measure every fiftieth segment from each mold. If variations occur, re-check mold and repair if necessary.

3. For any mold modified or repaired, re-check dimensions of the mold prior to using the mold in production, and check dimensions of the first segment and every 25th segment from this mold.

4. The Resident Engineer may elect to reduce the frequency of ring dimension checks based on consistently meeting the required tolerances.

B. Mockup or Ring Fit-Up:

1. Prior to beginning production of the precast concrete segments, completely assemble and survey two sets of two each pre-production segment rings cast from proposed molds, including compression packing and connections but without gaskets. Circumferential joint dowels may be replaced with temporary steel dowels to aid in ring disassembly. If universal tapered rings are proposed, only one set of two segment rings is required.

   a. Assemble each set of rings separately at the place of manufacture by stacking segment rings one on top of another on a level, flat surface with joints staggered.

   b. Assemble one full set of rings for each type: one left taper, one right taper, or one universal taper.

   c. Survey the rings to verify that the molds and segments as cast meet fabrication tolerances as indicated on the Contract Drawings.

   d. Adjust or replace forms as required to meet specified requirements.

2. The Resident Engineer will select the bottom ring from one of the two sets to be retained as the master ring for the duration of segment casting operations to verify compliance with fabrication tolerances for the production segments using the same 2-ring configuration.

   a. Select segments for the upper trial ring in accordance with the following:

      1) Every 500th segment cast from each mold.

      2) Mold repair or replacement: First segment ring cast and every 250th cast thereafter.

   b. Survey the segment rings to verify that the molds and segments meet fabrication and fit-up tolerances as indicated on the Contract Drawings.
3. The Resident Engineer may elect to reduce the frequency of ring fit-up demonstrations based on consistently meeting the required tolerances.

C. Testing:

1. Perform gasket tests of type required and recommended by manufacturer to demonstrate compliance with design criteria specified herein. As a minimum, perform the following tests:
   a. Watertightness tests: Assure no leakage for anticipated combinations of gaps and offsets, and at pressures specified herein. Test both straight gaskets and T-joint configurations.
   b. Reaction load tests: Perform sufficient tests to develop correlations, for both no offset and maximum offset, between compression loads on the gasket and gap.
   c. Stress relaxation tests: As a minimum, measure reaction loads over a period of three months at 160 degrees F for a no offset condition. Use a load-time plot and engineering analysis to determine stress relaxation at 100 years.

2. Perform trial mix and production concrete testing in accordance with Section 03 05 15, Portland Cement Concrete.

D. Repair of Defects:

1. Segments which exhibit structural damage that will impair the ability of the segment to perform as required, in the opinion of the Resident Engineer, will be rejected. Examples of this type of structural damage include cracks greater than 0.008 inches wide through the full thickness of the segment; multiple cracks at joint bearing areas or inserts; spalling, chipping or cracking that exposes rebar; and honeycombing, cracking or spalling at gasket groove locations that will compromise water sealing capability.

2. For non-structural defects or damage, repair segments per approved repair procedures. Provide repair procedures for patching of blow holes and air voids; chipping and spalling; local protrusions; localized surface cracking; structural cracks less than 0.008 inch; and honeycombing not adjacent to gasket grooves or joint bearing areas.

3. For minor non-structural defects not located at bearing areas or gasket groove locations and less than 3/16 inch in depth, no repairs are required.

4. Do not transport repaired segments to the Site prior to approval of repairs by the Resident Engineer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Clean the segment erection area to remove water, dirt, debris, and other foreign material prior to erecting each segment ring.

B. Remove foreign material from segments prior to their erection.

C. Set segments to the required joint gap using the TBM segment erector.
D. Do not use the segment bolts or other positively interlocking elements to compress segment gaskets, but only to maintain segment gaskets in the compressed position.

E. Completely erect and fasten segments within the TBM tail shield before thrusting TBM forward.

F. Erect segment rings to stagger longitudinal joints in adjacent rings.

G. Examine segments for structural damage. Repair or replace misaligned or damaged segments to maintain tolerances, to maintain water-tightness, and to ensure stability and safety during construction.

H. Correct improper installation of the segments at any particular location within the tail shield prior to the injection of tail void grout behind the segments at that location, and before the TBM has completed more than 25 percent of the subsequent maximum stroke.

I. Modify construction methods to eliminate future reoccurrence of improper installation and implement additional monitoring of the segment ring to assure compliance with specified Groundwater Seepage and tolerance requirements.

J. Check plane of leading edge of circumferential joint to provide a uniform thrust surface for TBM rams.

K. Perform systematic tail void grouting in accordance with Section 31 73 23, Tail Void Grouting.

3.02 CONSTRUCTION

A. Coordinate tunnel excavation and installation of segmental lining:
   1. To accommodate the cast-in-place invert slab, attachments to the lining, and cross-passage construction.
   2. To accommodate additional requirements as may be required by the Contractor’s means and methods for performing tunnel excavation, segmental lining, and ancillary work.

B. Use tapered rings as the exclusive means for negotiating curves and for making alignment corrections.

C. For longitudinal segment joints:
   1. Do not use compression packing of variable thickness.
   2. Use only one compression packing per joint.

D. Regardless of the type of mechanical joint connector, do not remove them subsequent to their installation unless immediately replaced.

E. Protect gasket materials and gaskets on stored segments from UV exposure.

F. Precast Segment Repair or Replacement
   1. Do not install segments which exhibit any of the following damage:
      a. Visible reinforcement.
      b. Cracks in excess of 1/8-inch width at any location.
c. Spalling in any amount adjacent to or affecting gasket or positively interlocking element seating or confinement.

2. Replace segments that have been installed against which the TBM has not completed more than 25 percent of the subsequent maximum stroke and which exhibit damage as detailed herein.

3. Repair segments before TBM has advanced beyond 300 feet of damaged area which exhibit the following:
   a. Spalling to a depth in excess of 1-inch.
   b. Characteristics specified herein prohibiting installation.

3.03 FIELD QUALITY CONTROL

A. Establish a program for measuring the deformation of the segmental lining system under load:
   1. Install four anchors at 90-degree spacing at every 25th segment ring under the guidance of the Resident Engineer for tape extensometer measurements.
   2. Measure deformations and compare to previously recorded measurements.

B. Inspect the conditions and the competence of segmental lining:
   1. Daily, where installed.
   2. Immediately after each shove of the TBM.
   3. During and upon completion of tail void grouting.

C. Monitor the installation of each segment ring as related to the uniformity of the void space between the segment ring and the tail shield. Record the distance between the inside diameter of the tail shield and the outside diameter of the segment ring. Measure this distance at four locations approximately 90 degrees apart at the leading edge of the ring, at the following times:
   1. Take the first set of measurements upon erecting the segment ring, but prior to thrusting against the ring.
   2. Take the last set of measurements upon completing the TBM shove, but prior to installing the next segment ring.
   3. Resident Engineer may elect to eliminate some or all of these Contractor measurements if it becomes evident to the Resident Engineer, through visual or other means, that the Contractor is consistently erecting the segment rings in accordance with specified requirements.

D. Monitor the installation of each segment ring before and after shove as related to the indicated circularity tolerances.

E. Survey of Completed Lining: In accordance with Section 31 71 19, Tunnel Excavation by Tunnel Boring Machine.

F. Notifications - Notify the Resident Engineer:
   1. 15 days in advance of assembling demonstration segment rings.
2. Within 1 day of removing a segment casting mold from service for repair or replacement:
   a. Provide survey results to verify conformance of repaired or replacement mold to tolerance requirements.
   b. In cases of repair, submit written report including the nature of the damage and the method of repair.

3. Immediately, upon discovering precast segments that do not conform to the requirements of the Contractor's design and the minimum design requirements set forth herein, promptly rectify the non-conformance.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for materials, proportioning, and application of shotcrete for both temporary and permanent work. This includes shotcrete used for both the initial and final tunnel linings within the cross passages. Unless indicated otherwise, the requirements specified apply to both temporary and permanent shotcrete.

B. This Section covers both wet-mix and dry-mix shotcrete.

C. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections not referenced below may also be related to the proper performance of this work.

1. Section 03 20 00, Concrete Reinforcing.
2. Section 03 24 00, Fibrous Reinforcing.
4. Section 31 74 19.10, Initial Shotcrete Tunnel Lining.
5. Section 31 74 19.20, Final Shotcrete Tunnel Lining.
6. Section 01 74 01, Excavation Spoils and Muck Disposal.

1.02 REFERENCES

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

1. American Concrete Institute (ACI)
   a. ACI 301 Specifications for Structural Concrete for Buildings, Article 5.7.1 and Chapter 9.
   b. ACI 506R Guide to Shotcrete
   c. ACI 506.2 Specification for Materials, Proportioning, and Application of Shotcrete
   d. ACI 506.4R Evaluation of In-Place Shotcrete
   e. ACI C 660 Shotcrete Nozzlemans Certification

   a. ASTM A 185 Specifications for Wire Fabric, Plain, Welded Steel for Concrete Reinforcement
b. ASTM A 615 Standard Specifications for Bars, Deformed and Plain, Carbon-Steel Bars, for Concrete Reinforcement.

c. ASTM A 820 Standard Specifications for Steel Fibers for Fiber-Reinforced Concrete.

d. ASTM C 31 Standard Practice for Making and Curing Concrete Test Specimens in the Field.

e. ASTM C 33 Standard Specification for Concrete Aggregates

f. ASTM C 39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens

g. ASTM C 42 Standard Test Methods for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete

h. ASTM C 94 Standard Specification for Ready-Mixed Concrete

i. ASTM C 109 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in or [50mm] cube Specimen)

j. ASTM C 143 Standard Test Method for Slump of Hydraulic Cement Concrete

k. ASTM C 150 Standard Specification for Portland Cement

l. ASTM C 171 Standard Specification for Sheet Materials for Curing Concrete

m. ASTM C 288 Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)

n. ASTM C 309 Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

o. ASTM C 595 Standard Specification for Blended Hydraulic Cements

p. ASTM C 618 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete

q. ASTM C 642 Standard Test Method for Density, Absorption, and Voids in Hardened Concrete

r. ASTM C 685 Standard Specification for Concrete Made by Volumetric Batching and Continuous Mixing

s. ASTM C 803 Standard Test Method for Penetration Resistance of Hardened Concrete

t. ASTM C 989 Standard Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars

u. ASTM C 1074 Standard Practice for Estimating Concrete Strength by the Maturity Method

v. ASTM C 1116 Standard Specification for Fiber Reinforced Concrete and Shotcrete
1.03 DEFINITIONS

Refer to the following Sections:

1. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method.
2. Section 31 74 19.10, Initial Shotcrete Tunnel Lining.
3. Section 31 74 19.20, Final Shotcrete Tunnel Lining.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit at least 90 days prior to commencement of shotcrete application the proposed mix characteristics including:

1. All proposed mix design proportions by weight and volume, including tolerances
2. Projected strength development vs. time
3. Design slump
4. Water-cement ratio
5. Source of aggregates, gradation ranges, and quantities
6. Mix water source
7. Cement type, brand, and quantity
8. Supplementary cementing material type (silica fume, fly ash) and quantities
9. Chemical admixture types (data sheets) and quantities
10. Test results

C. Submit preconstruction testing results at least 30 days prior to commencement of shotcrete work.

D. Submit resumes for proposed shotcrete nozzlemen and foremen at least 90 days prior to commencement of shotcrete work.
E. Submit details of shotcrete equipment to be used on the Contract, including brand name, model and capacity of pump and air compressor, at least 90 days prior to commencement of shotcrete work.

F. A description of the proposed curing procedures and protection to be provided to shotcrete.

1.05 QUALITY CONTROL

A. Shotcrete Crew Qualifications: Shotcrete crew foremen and nozzlemen shall meet the following requirements.

1. Furnish proof that each shotcrete crew foreman has at least 5 years experience in underground shotcrete application on projects of a similar character to this Contract along with three references from persons responsible for supervision of these projects. Include name, address and telephone number for all references.

2. Furnish proof that all nozzlemen are certified to ACI C 660 for application of shotcrete to vertical and overhead surfaces for both wet- and dry-mix shotcrete. Furnish proof that nozzlemen have successfully completed three projects of similar character to this Contract. All nozzlemen must shoot test panels that fulfill the requirements of Article 1.05B below.

B. Preconstruction testing

1. Test Panels: Prepare preconstruction test panels for examination by the Resident Engineer prior to job shotcrete placement. Preparation and testing shall comply with ASTM C 1140, except as modified below:

   a. Test panel size shall be 24 inches by 24 inches minimum, with a minimum depth of 4-1/2 inches. Panels shall be made with sloped sides.

   b. Coring and testing shall be in compliance with ASTM C 42, except that minimum core size shall be 4-inch diameter by 4-1/2 inches deep, trimmed to 4 inches long. Apply ASTM C 42 length-to-diameter correction factors to the compressive strength results.

   c. Cores shall not be taken closer than 4 inches from any edge of the panel.

2. Concrete or Shotcrete Mix Testing: Produce test panels for each proposed mix.

   a. Provide test panels without reinforcing. Obtain at least six test specimens from each panel.

   b. Test the nonreinforced specimens for compliance with the specified physical properties in accordance with ASTM C 42.

   c. Test admixtures for compatibility with cement in accordance with ASTM C 1141.

   d. Confirm design slump for each wet-mix shotcrete mix.

3. Nozzleman Qualification: Produce test panels for each proposed nozzleman and each anticipated shooting orientation.
a. Provide test panels with reinforcing that reproduces the thickest and most congested area specified for the structure as identified by the Resident Engineer.

b. Test panels shall be shot using the same nozzleman, assistant, and equipment that will be used under the Contract, and with each of the approved concrete mix designs and at orientations to be used under the Contract.

c. Shotcrete used shall be within ±1/2 inch of the design slump.

d. Test panels for nozzleman qualification shall not be shot until the shotcrete mix is approved.

e. Visually grade the reinforced specimens for compliance with specified core grade in accordance with Article 1.05D Shotcrete core grades for test panels and permanent shotcrete.

f. Extract five cores from locations of reinforcing steel in the test panel. If any one core is graded higher than 3 or with more than two of the five cores having a core grade of 3, the entire test panel is rejected.

g. When the prequalification test panel is rejected, a second panel may be shot. When the second test panel is rejected, the nozzleman will not be permitted to shoot on the Contract.

4. Fiber-reinforced shotcrete: Produce three circular test panels for each 7-day and 28-day testing and perform toughness testing in accordance with ASTM C1550.

5. Undertake a full-scale trial of permanent shotcrete application to the membrane waterproofing:

   a. Complete trial at least 60 days prior to commencement of permanent shotcrete work.

   b. Fix waterproofing membrane system, per approved method statement, to an outer form with a 3-inch minimum thick shotcrete initial lining, which is representative of a 10-foot long section of the cross passage geometry.

   c. Apply wire mesh and final lining shotcrete to membrane over the full length to a uniform thickness of 10 inches utilizing the same personnel, equipment, materials and methods as proposed for the works, including finishing.

   d. Extract, evaluate and test six three-core sets in accordance with Articles 1.05B.1.b and c, and 1.05D.

   e. In addition, the outer form shall be carefully removed once the design shotcrete 28-day strength has been achieved. The condition of the waterproofing membrane shall be recorded before the final lining is removed.

   f. The results of this trial shall be approved by the Resident Engineer prior to the commencement of the permanent shotcrete work.

C. Construction testing
1. Produce a material test panel for each mix and each work day. Test panel shall be kept moist and at 70 degrees F +/- 10 degrees F until moved to an Independent Testing Laboratory. Test specimens from test panels in compliance with ASTM C 1140, except as modified below:

   a. Test panel size shall be 24 inches by 24 inches minimum, with a minimum depth of 4-1/2 inches. Panels shall be made with sloped sides.
   b. Test panels shall be shot at the same orientation and in the same manner as the work.
   c. Test panels shall be marked for later identification (mix, location, date, nozzleman).

2. Test specimens from core drilling of in-place shotcrete:

   a. Coring and testing shall be in compliance with ASTM C 42, except that minimum core size shall be 4-inch diameter by 4-1/2 inches deep, trimmed to 4 inches long. Apply ASTM C 42 length-to-diameter correction factors to the compressive strength results.
   b. Perform core sampling and testing at locations determined by the Resident Engineer up to a maximum of fifty 3-core sets.
   c. Fill all core holes with non-shrink grout that has a 28-day compressive strength of 5000 psi minimum. Prepare hole in accordance with grout manufacturer’s instructions and finish flush with the surrounding shotcrete.
   d. In-place coring of permanent shotcrete shall not penetrate nor come within 4 inches of the waterproof membrane.
   e. Cores shall be clearly marked for later identification (mix, location, date, nozzleman).

3. Grade cores that include reinforcement in accordance with Article 1.05D – Shotcrete core grades for test panels and permanent shotcrete.

4. The mean compressive strength of a set of three cores shall equal or exceed 0.85 f’c with no individual core less than 0.75 f’c.

5. Requirements for construction testing of steel fiber reinforced shotcrete (SFRS) are provided in Paragraph 2.08 below.

D. Shotcrete core grades for test panels and permanent shotcrete (Refer to ACI 506.2 for photographs of graded cores):

   1. Grade 1: Shotcrete specimens are solid; there are no laminations, sandy areas, or voids. Small air voids with a maximum diameter of 1/8 inch and maximum length of 1/4 inch are normal and acceptable. Sand pockets or voids behind continuous reinforcing steel are unacceptable. The surface against the form or bond plane shall be sound, without a sandy texture, or voids.

   2. Grade 2: Shotcrete specimens shall have no more than two laminations or sandy areas with dimensions not to exceed 1/8 inch thick by 1 inch long. The height, width and depth of voids shall not exceed 3/8 inch in any direction. Porous areas behind reinforcing steel shall not exceed 1/2 inch in any direction except along
the length of the reinforcing steel. The surface against the form or bond plane shall be sound, without a sandy texture or voids.

3. Grade 3: Shotcrete specimens shall have no more than two laminations or sandy areas, with dimensions exceeding 3/16 inch thick by 1-1/4 inches long, or one major void, sand pocket, or lamination containing loosely bonded sand not to exceed 5/8 inch thick and 1-1/4 inches in width. The surface against the form or bond plane may be sandy with voids containing overspray to a depth of 1/16 inch.

4. Grade 4: The core shall meet in general the requirements of Grade 3 cores, but may have two major flaws such as described for Grade 3 or may have one flaw with a maximum dimension of 1 inch perpendicular to the face of the core with a maximum width of 1-1/2 inches. The end of the core that was shot against the form may be sandy and with voids containing overspray to a depth of 1/8 inch.

5. Grade 5: A core that does not meet the criteria of core grades 1 through 4, by being of poorer quality, shall be classified as Grade 5.

E. Evaluation of in-place shotcrete

1. Remove and replace shotcrete that is delaminated, exhibits laminations, voids, or sand pockets exceeding the limits for the specified grade of shotcrete. Remove and replace shotcrete that does not comply with the specified material properties. Repair core holes in accordance with Chapter 9 of ACI 301 and Article 1.05C.2.c above.

F. Acceptance

1. The Resident Engineer has the authority to accept or reject shotcrete work. Shotcrete which does not conform to these Specifications may be rejected either during the shotcrete application process, or on the basis of tests from either test panels or the completed work.

2. Deficiencies observed during the shotcrete application process such as, but not limited to, the following constitute a cause for shotcrete rejection:
   a. Failure to properly control and remove build-up of overspray and rebound;
   b. Incomplete consolidation of shotcrete behind and around reinforcing steel, mesh and anchors;
   c. Incorporation of sand lenses, excessive voids, delaminations, sags or sloughing;
   d. Failure to apply shotcrete to the required line, grade and tolerance.

3. Wherever possible perform remedial work to correct deficiencies while shotcrete is still plastic.

4. Hardened shotcrete will be examined by the Resident Engineer for any evidence of excessive plastic or shrinkage cracking, tears, feather-edging, sloughs or other deficiencies. Sounding shall be used to check for delaminations.

5. Extract five cores from locations of reinforcing steel in the test panel. If any one core is graded higher than Core Grade 3 or with more than two of the five cores having a Core Grade of 3, the entire test panel is a failure.
6. If the results of compliance tests from shotcrete test panels, or assessment of the plastic or hardened shotcrete indicate non-conformance of the shotcrete, the Resident Engineer will implement a program of evaluation of the in-place shotcrete. Such evaluation shall include, but not be limited to:

   a. Extraction of cores from in-place shotcrete at locations selected by the Resident Engineer and testing of such cores for compliance.

   b. Checking for delaminations using sounding or other appropriate non-destructive testing procedures.

   c. Bond pull-off testing.

   d. Diamond saw cutting or coring to check adequacy of encasement of reinforcing steel and anchors.

7. Rejected shotcrete shall be removed and the lining rebuilt to the satisfaction of the Resident Engineer, or the lining may be strengthened as approved by the Resident Engineer, all at no cost to Sound Transit. Rejected steel fiber reinforced shotcrete may be strengthened by the addition to the intrados of a minimum of one layer of welded wire mesh and 3 inches of plain shotcrete. Additional reinforcing or shotcrete may be required as directed by the Resident Engineer at no cost to Sound Transit.

8. Upon approval of the Resident Engineer, steel fiber reinforced shotcrete (SFRS) in lieu of wire mesh reinforcement may be used for certain underground structures, or certain parts of the shotcrete lining. If the performance of the SFRS is not satisfactory, such approval may be revoked.

PART 2 - MATERIALS

2.01 CEMENT

A. Portland cement: ASTM C 150, Type II.

2.02 AGGREGATE

A. Normal weight aggregate: ASTM C 33. Aggregate not meeting ASTM C 33 may be used provided preconstruction tests demonstrate the shotcrete meets all other specified requirements.

B. Lightweight aggregate: not permitted.

C. Maximum aggregate size: 3/4 inch.

D. Additional requirements for permanent shotcrete: Potential reactivity of aggregates: Use only aggregates classified as innocuous in accordance with ASTM C 288.

2.03 REINFORCEMENT

A. Deformed steel reinforcement: ASTM A 615.

B. Welded wire fabric: ASTM A 185. The minimum quantity of welded wire fabric kept on site and available for immediate use shall be equivalent to one week of production for each heading under construction, including headings constructed using steel fiber reinforced shotcrete initial linings.
C. Steel fibers for Initial Shotcrete Lining: As specified in Section 03 24 00, Fibrous Reinforcing.

D. Polypropylene Fibers for Final Shotcrete Lining: As specified in Section 03 24 00, Fibrous Reinforcing.

E. Glass fibers: Not permitted.

2.04 WATER

A. Clean and potable.

B. Mixing water for shotcrete shall meet requirements of ASTM C 94.

2.05 ADMIXTURES

A. Water-reducing and superplasticizer: ASTM C 1141.

B. Retarding: ASTM C 1141.

C. Accelerating: ASTM C 1141. In addition, accelerating admixtures for permanent shotcrete shall meet the following requirements:

1. Liquid, non-aggressive type accelerator.

2. Provide a signed statement from certified Independent Testing Laboratory or cement manufacturer that proposed accelerator and dosing is compatible with cement.


E. Fly ash and natural pozzolans: ASTM C 618.

F. Ground granulated blast-furnace slag: ASTM C 989.

G. Silica fume: ASTM C 1240.

2.06 CURING MATERIALS FOR PERMANENT SHOTCRETE

A. Curing materials that cause stains on architectural finishes shall not be used.

B. Sheet materials: ASTM C 171.

C. Curing compounds: ASTM C 309, apply as recommended by manufacturers.

2.07 PROPORTIONING

A. Select shotcrete proportions to produce the specified material properties.

B. Shotcrete mix proportions for all shotcrete, including preconstruction test mixes, using normal weight aggregate shall produce the following compressive strengths:

<table>
<thead>
<tr>
<th>SHOTCRETE APPLICATION</th>
<th>AGE OF SHOTCRETE</th>
<th>$F'_c$, PSI</th>
<th>ASTM TEST METHOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary only</td>
<td>1 hour</td>
<td>100</td>
<td>C 803</td>
</tr>
<tr>
<td>Temporary only</td>
<td>24 hours</td>
<td>2,000</td>
<td>C 1074 or C 39</td>
</tr>
<tr>
<td>Temporary only</td>
<td>7 days</td>
<td>4,000</td>
<td>C 39</td>
</tr>
</tbody>
</table>
Both temporary and permanent 28 days 5,000 C 39

C. Minimum slump of wet-mix shotcrete shall be 1 inch. Actual value shall be determined from preconstruction trials.

D. In addition to the above proportioning requirements, permanent shotcrete shall meet the following:

1. Maximum water/cement ratio: 0.40.
2. As-shot air content: 3.5 to 5 percent.

2.08 STEEL FIBER-REINFORCED SHOTCRETE (SFRS)

A. SFRS to conform to ASTM C 1116.

B. In addition to the requirements of Articles 2.07B and 2.03C, mix proportions for SFRS shotcrete shall produce the following properties:

<table>
<thead>
<tr>
<th>AGE OF SHOTCRETE FROM TIME OF BATCHING</th>
<th>AVERAGE ENERGY ABSORPTION (ASTM C 1550)</th>
<th>DEFLECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 days</td>
<td>350 Joules</td>
<td>1.5 in</td>
</tr>
<tr>
<td>28 days</td>
<td>450 Joules</td>
<td>1.5 in</td>
</tr>
</tbody>
</table>

C. Toughness Performance Level Testing:

1. Perform toughness performance level testing in accordance with the procedures provided in ASTM C1550.
2. Perform one set of tests as defined in Article 2.08.C for each cross passage at the commencement of excavation.
3. One set of tests shall consist of a minimum of three panels each for shotcrete age of 7 and 28-days, for a total of six tests.
4. If the specified performance criteria are not met, notify the Resident Engineer immediately.
5. Submit results within 1 day of the testing.

2.09 PRE-BAGGED MATERIALS

A. Pre-bagged materials are allowable with pre-dampening prior to use.

2.10 DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle materials to prevent contamination, segregation, corrosion, or damage.

B. Store shotcrete materials, including steel fibers, in a dry place.

C. Store aggregate materials at a minimum temperature of 40 degrees F.

D. Store liquid admixtures to prevent evaporation and freezing. Store admixtures at all times in clearly marked and labeled containers (including admixture name, type, storage
requirements, use-before date, instructions for use, safety precautions, and manufacturer’s recommended dosage range).

2.11 EQUIPMENT

A. Use batching equipment that proportions aggregate and cement mixtures by weight. Batching by volume is not permitted.

B. Use an air supply system that delivers air uncontaminated by oil or any other contaminant and that is capable of maintaining a constant pressure.

C. Shotcrete delivery equipment shall be capable of delivering a steady stream of uniformly mixed material to the discharge nozzle at the proper velocity and rate of discharge.

D. Use positive displacement pumps equipped with hydraulic or mechanically powered pistons, with compressed air added at the discharge nozzle, for wet-mix shotcrete application.

E. Monitor air ring at nozzle for signs of blockage of individual air holes. Stop shooting and clean air ring if non-uniform discharge of shotcrete becomes apparent.

F. Clean shotcrete delivery equipment thoroughly at the end of each shift. Regularly inspect and clean air ring and nozzle; replace if required.

G. Provide a separate air hose and blow pipe, capable of simultaneous operation with shotcreting operation, for removal of rebound and dust.

H. Equipment will be subject to approval of the Resident Engineer. Maintain equipment in proper working order. Provide additional test panels and test cores as required by the Resident Engineer to demonstrate that the equipment is functioning properly during shotcreting operation.

I. Provide standby equipment on site and in good working order at all times during shotcreting operations.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Verify that placement and clearance around reinforcement (including wire mesh) is adequate for complete encasement.

B. Verify that surfaces to receive shotcrete have been properly prepared according to the Contract Documents.

C. Remove rebound and any other foreign material from construction joints prior to continuing shotcrete installation.

D. Rebound shotcrete shall not be reused or incorporated into the work.

E. Sequence of shotcrete installation shall be as shown on the Contract Drawings. Thickness indicated is the minimum thickness at any point. Use thickness indicators to control and verify thickness.

3.02 BATCHING AND MIXING

A. Weight batching shall comply with the accuracy specified in ASTM C 94.
B. Use batching and mixing equipment capable of proportioning and mixing the required materials.

C. Use feed systems for all materials that are interconnected such that if one feed stops, all feeds stop.

D. Shoot dry-mix shotcrete material within 45 minutes after batching or pre-dampening.

E. Shoot wet-mix shotcrete material within 90 minutes after batching.

F. Dosing of admixture by hand is not permitted.

G. Shotcrete delivered to shotcrete pump with a slump that is outside the confirmed design range will be rejected.

3.03 SURFACE PREPARATION

A. Soils: Prepare surfaces to line and grade. Dampen surface immediately prior to shooting.

B. Concrete and Shotcrete: Remove all deteriorated, loose, unsound material or contaminants that may inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness. Taper edges to approximately 45 degrees to eliminate square shoulders at the perimeter of a cavity. Surface shall be saturated surface dry (SSD) immediately prior to placing shotcrete.

C. Structural Reinforcement, including Wire Mesh: The surface shall be free of deleterious materials that inhibit bonding. For new construction, reinforcement laps shall be separated with a clearance of at least three times the diameter of largest aggregate. Reinforcement shall be secured to prevent movement.

D. Forms: Secure forms to minimize the effects of vibration. Construct forms to allow escape of placement air and rebound.

E. Water Leaks: Securely attach drainage pipes, channels or similar prior and during temporary shotcreting.

F. Membrane Waterproofing: Remove loose material, mud, or any other foreign material that will prevent bonding. Clean surface with compressed air. Repair any damage to the membrane prior to shotcrete application. Obtain signed statement for each cross passages from the Resident Engineer and waterproofing installer that membrane waterproofing system is free of defects prior to final shotcrete lining installation.

3.04 JOINTS

A. Construction Joints: Taper construction joints at a 1 to 1 slope where joint is not subject to compression loads. Form square joints where joints are subject to compression loads. Surface preparation of joints shall comply with Article 3.03B. Continue reinforcement through construction joint.

B. Control Joints: Place as shown on Contract Drawings. Discontinue reinforcement and wire mesh at control joints.

3.05 ALIGNMENT CONTROL

A. Install taut ground wires, lattice girders and other means to establish thickness and plane of required surface.

B. Install taut ground wires or other means at corners or offsets not established by forms.
3.06 APPLICATION

A. Shotcrete Placement Technique

1. Provide a platform that permits nozzleman unobstructed access to the receiving surface. Remove rebound and overspray from previously prepared surfaces prior to shotcrete placement.

2. Apply shotcrete from the bottom and continue upwards to avoid the inclusion of rebound in the lining.

3. For invert lining, use separately controlled air blowpipe during spraying to remove rebound from the lining.

4. Spraying shotcrete through more than one layer of reinforcement or mesh is not permitted.

5. Place shotcrete first in corners, recesses, and other areas where rebound or overspray cannot escape easily. Place shotcrete with nozzle held at approximately 90-degree angle to the receiving surface. In corners, direct nozzle at approximately 45-degree angle or bisect the corner angle.

6. Velocity and spraying distance shall be the optimum for maximum shotcrete adherence and compaction.

7. Apply shotcrete so sags or sloughing do not occur. Where movement of shotcrete has occurred adjacent to a slough-off, the shotcrete in question shall be removed.

8. Discontinue shooting or shield the nozzle stream if wind causes separation of ingredients during shooting.

9. Do not reuse rebound, sprayed fibers, or overspray.

10. Remove laitance and any foreign material from shotcrete surfaces to receive additional shotcrete layers. Surface preparation after final set shall comply with Article 3.03B.

11. Prior of shotcrete application, control groundwater inflow and seepage to prevent dissolution of cement and fine aggregates in the fresh shotcrete. Control groundwater as shown on the Contract Drawings and specified, or by other appropriate and approved methods. Do not apply shotcrete on surfaces with standing water.

12. Remove hardened overspray and rebound from adjacent surfaces, including exposed reinforcement.

B. Encasement of Reinforcement, including Wire Fabric: Place shotcrete to completely encase reinforcing steel. Encase reinforcement by shooting with sufficient velocity and plasticity so material flows around and behind the reinforcement. Front face of reinforcement shall remain clean during encasement. Place shotcrete to provide the cover over reinforcement required by ACI 301.

C. Applying shotcrete against the membrane waterproofing shall be carried out in a manner that prevents damage to the membrane.
D. For permanent shotcrete, apply shotcrete in continuous layer thicknesses between 3 and 6 inches per pass. Test bond strength between layers as directed by the Resident Engineer.

3.07 FINISHING

A. Temporary shotcrete: as specified in Section 31 74 19.10, Initial Shotcrete Tunnel Lining.
B. Permanent shotcrete: as specified in Section 31 74 19.20, Final Shotcrete Tunnel Lining.

3.08 CURING

A. Permanent Shotcrete: Immediately after finishing, cure shotcrete continuously by maintaining in a moist condition for 7 days or until specified strength is attained or until succeeding shotcrete layers are placed. Cure by one of the following methods:
   1. Ponding or continuous sprinkling.
   2. Covering with an absorptive mat or sand that is kept continuously wet.
   3. Covering with impervious sheet material.
   4. Curing compounds: subject to prior approval by the Resident Engineer.
   5. Curing compounds which impair bonds shall not be used where a further layer of shotcrete is to be applied.
B. Temporary Shotcrete: Natural curing is permitted.

3.09 HOT WEATHER SHOTCRETING

A. Do not place shotcrete when shotcrete material temperature is above 90 degrees F for wet-mix; 100 degrees F for dry mix. Lower temperature of reinforcement and receiving surfaces below 100 degrees F prior to placing shotcrete.

3.10 COLD WEATHER SHOTCRETING

A. Placing shotcrete may proceed when ambient temperature is 40 degrees F and rising. Placing shotcrete shall discontinue when ambient temperature is 40 degrees F and falling unless protective measures are taken to protect shotcrete. Shotcrete material temperature, when placed, shall not be less than 50 degrees F. Applicable procedures used for cold weather concreting may be used for cold weather shotcreting. Protection against frost shall be maintained until the shotcrete has developed a compressive strength of 2,000 psi.

3.11 PROTECTION

A. Protect surfaces not intended for shotcrete placement from deposit of rebound and overspray or impact from nozzle stream.
   1. Remove rebound and hardened overspray from final shotcrete surfaces and from areas not intended for shotcrete placement, and dispose in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.

END OF SECTION
SECTION 31 74 19.10
INITIAL SHOTCRETE TUNNEL LINING

PART 1 - GENERAL

1.01 SUMMARY

A. This section includes specifications for the installation of initial shotcrete linings for the cross passages as shown on the Contract Drawings.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 20 00, Concrete Reinforcing.
2. Section 03 24 00, Fibrous Reinforcing.
4. Section 31 74 19.05 Shotcrete for SEM Tunnels.
5. Section 31 74 19.20, Final Shotcrete Tunnel Lining.
6. Section 01 74 01, Excavation Spoils and Muck Disposal.

1.02 REFERENCES

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

1. American Concrete Institute (ACI)
   a. ACI 506R Guide to Shotcrete
   b. ACI 506.2 Specification for Shotcrete

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   b. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

3. American Welding Society (AWS):
   a. AWS D1.1 Structural Welding Code

1.03 DEFINITIONS

A. Dry-mix Shotcrete: Shotcrete that is supplied in dry form with water added at the nozzle.

B. Flashcrete: Initial layer of steel fiber reinforced shotcrete applied to exposed ground immediately after excavation.
C. Wet-mix Shotcrete: Shotcrete that is supplied from an on-site batch plant or ready-mix concrete supplier, including water in the mix.

D. Lattice Girder: Lightweight, three-dimensional steel frame member shop-fabricated from steel bar stock or reinforcing steel, embedded in the shotcrete lining and used to provide support and dimensional guidance.

E. Splice Bar: Rebar installed to provide mechanical connection of shotcrete in the circumferential direction between the top heading and bench shotcrete linings and at other construction joints.

F. Splice Clip: Rebar installed at the cross passage arch lines to provide longitudinal reinforcement of the shotcrete lining.

G. Waste Shotcrete: Discarded shotcrete and flashcrete materials, including overspray, rebound, loose and broken or otherwise excavated initial shotcrete linings and associated materials (e.g. steel fibers).

H. Wavelength: Distance between two crests used in the determination of the smoothness of the shotcrete surface before installation of the waterproofing membrane

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Samples:
   1. Submit for each lattice girder type to be used:
      a. Two-foot long piece of the full cross-section - two samples.
      b. Butt plate splice mock-up.
      c. Lap splice mock-up.

C. Shop Drawings:
   1. Shotcrete lining shop drawings indicating all structural and construction details and geometry including, but not limited to the following:
      a. Tolerances.
      b. Plan and sequence of excavation and lining installation.
   2. Lattice girder shop drawings, including specifications and fabrication details.

D. Product Information: Lattice girders.

1.05 QUALITY ASSURANCE

A. Shotcrete:
   1. Material and application specified in Section 31 74 19.05, Shotcrete for SEM Tunnels
   2. Visual Inspection:
      a. Smoothness criteria: Do not exceed a depth to wavelength ratio of 1/60 measured with a 10-foot straight edge in the longitudinal direction and
deviation from the theoretical curved surface in the circumferential direction.

b. Thickness indicators: Install appropriate thickness indicators to verify lining thickness.

3. Sample coring and testing: Section 31 74 19.05, Shotcrete for SEM Tunnels.

4. Recording: for every application of shotcrete, record the following information into the daily shift report:
   a. Date, shift, and tunnel temperature.
   b. Nozzleman.
   c. Test cylinders cast and cores drilled, including name of technician and sample identification.
   d. Results of visual inspection.
   e. Locations and volumes applied.

B. Lattice Girders:

   1. Test lattice girders prior to the start of construction as follows:
      a. Three random samples of typical lengths to be installed, selected by the Resident Engineer.
      b. Provide manufacturer’s certification that lattice girders meet specified performance requirements.
      c. All lattice girders will be rejected if any one sample fails to meet specified requirements.

1.06 DELIVERY, STORAGE AND HANDLING

A. General:

   1. Load, transport, unload and store all structural materials so that they remain clean and protected from damage.
   2. Store cementitious materials in dry, protected enclosures and in accordance with manufacturer’s recommendation.
   3. Store materials on platforms, skids or other supports above the ground surface.
   4. Damaged materials to be clearly marked and removed from site immediately.

B. Lattice Girders:

   1. Prevent bending, scraping, or overstressing members at all times.
   2. Protect projecting parts vulnerable to bending or damage during handling.
   3. Replace pieces bent or damaged unless repair is reviewed and accepted by the Resident Engineer.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Flashcrete: Steel fiber reinforced shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

B. Shotcrete: Wet- or dry-mix, as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

C. Lattice Girders:
   1. For all lattice girders use three primary reinforcing bars connected by stiffening elements of the manufacturer's design.
   2. Design the lattice girder to allow shotcrete to penetrate into and behind the girder without shotcrete shadowing.
   3. Section properties:
      a. As indicated on the Contract Drawings.
      b. A minimum of 5 percent of the moment of inertia shall be provided by the stiffening elements. This percentage will be calculated as an average along a repeatable length of the girder.
      c. The maximum centerline spacing of stiffening elements shall be less than three times the height of the girder to ensure stability against buckling, with a tolerance of plus or minus 1 inch.
   4. Material properties:
      a. Minimum physical properties of steel:
         1) Tensile Strength: 80 kilopounds per square inch (ksi) minimum.
         2) Yield Strength: 70 ksi minimum.
      b. Construct the connection elements at the end of the girder of structural angle or plate meeting the minimum properties of ASTM A36.
   5. Welding:
      a. Welding process to meet the requirements set forth by AWS for gas metal arc welding (GMAW). Ensure all welders are certified in accordance with AWS D1.1.
      b. Execute all welds parallel to the retaining bars with a minimum length of 1 inch.

D. Lattice Girder Accessories
   2. Splice Clips: Fabricated from No. 4 reinforcing bar in accordance with Section 03 20 00, Concrete Reinforcing.
3. Splice Bars: Fabricated from No. 4 reinforcing bar in accordance with Section 03 20 00, Concrete Reinforcing.

4. Butt and end plates: Plate meeting the minimum properties of ASTM A36

E. Steel Fiber: As specified in Section 03 24 00, Fibrous Reinforcing.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Flashcrete:

1. Apply minimum 2-inch layer of steel fiber reinforced shotcrete (flashcrete) immediately after excavation on all exposed surfaces to seal and protect the material from deterioration and initial loosening.

2. Apply flashcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

B. Lattice Girders:

1. Install to conform to the required shape of the initial lining shape. Consider variability of materials, excavation and erection tolerances, and initial lining deformation to determine actual dimensions.

2. Secure lattice girder segments by means of temporary wood blocking and tie rods or other means to maintain position during shotcreting.

3. Locate butt plates for lattice girder segment as shown on the Contract Drawings. Ensure a tight connection of all elements.

4. Remove temporary blocking prior to continuing shotcrete lining into bench and invert.

5. Remove all foreign material from splices prior to connection of subsequent lattice girder segment.

C. Splice Bars and Splice Clips: Install splice bars and splice clips as shown on the Contract Drawings.

D. Shotcrete:

1. Use steel fiber reinforced shotcrete (SFRS) for the initial lining for the cross passages.

2. Apply shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

3. Install shotcrete linings (including flashcrete layer) to provide thickness shown on the Contract Drawings. Use thickness indicators to ensure design thickness of shotcrete is achieved.

4. Remove and respray shotcrete not meeting specified quality.

5. Finish shotcrete as follows:
<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>FLATNESS CRITERIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary heading face flashcrete</td>
<td>No criteria</td>
</tr>
<tr>
<td>Tunnel flashcrete</td>
<td>No criteria</td>
</tr>
<tr>
<td>Tunnel initial lining</td>
<td>Article 1.05A.2.a</td>
</tr>
</tbody>
</table>

6. In addition to the initial lining, steel fiber reinforced shotcrete is to be covered with plain shotcrete with a minimum thickness of 1.5 inches prior to waterproofing installation (smoothing layer).

7. Remove all laitance, loose material, rebound, and Waste Shotcrete and dispose in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.

8. Shotcrete shall attain its full design strength before waterproofing is installed.

E. Jobsite Production and Safety

1. Maintain supply of steel fibers, lattice girders and admixtures on site equal to five days production on all tunnels under construction, based on a rate of progress equal to the greater of the average rate achieved or the rate assumed in the Construction schedule.

2. Maintain a constant and adequate supply of steel fiber reinforced shotcrete at the tunnel heading during excavation to permit shotcrete to be applied at any time during the construction.

3. Ensure sufficient amount of steel fiber reinforced shotcrete to support one full excavation round is on site at all times during the excavation period. No excavation is permitted without sufficient shotcrete on site.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This section includes specifications for the installation of shotcrete final linings for the cross passages as shown on the Contract Drawings.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 03 20 00, Concrete Reinforcing.
2. Section 03 24 00, Fibrous Reinforcing.
3. Section 03 62 00, Non-shrink Grouting
4. Section 07 10 00, Waterproofing.
5. Section 31 71 23, Tunnel Excavation by Sequential Excavation Method
6. Section 31 74 19.05, Shotcrete for SEM Tunnels.
7. Section 01 74 01, Excavation Spoils and Muck Disposal.
8. Section 31 74 19.10, Initial Shotcrete Tunnel Lining.

1.02 REFERENCES

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

1. American Concrete Institute (ACI)
   a. ACI 506R Guide to Shotcrete
   b. ACI 506.2 Specification for Shotcrete

   a. ASTM A36 Standard Specification for Carbon Structural Steel
   b. ASTM A325 Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

3. American Welding Society (AWS):
   a. AWS D1.1 Structural Welding Code
1.03 DEFINITIONS

A. Dry-mix Shotcrete: Shotcrete that is supplied in dry form with water added at the nozzle.

B. Wet-mix Shotcrete: Shotcrete that is supplied from an on-site batch plant or ready-mix concrete supplier, including water in the mix.

C. Lattice Girder: Lightweight three-dimensional steel frame member shop-fabricated from steel bar stock or reinforcing steel, embedded in the shotcrete lining and used to reinforce the shotcrete lining and provide dimensional guidance.

D. Contact Grouting: Pressure injection of contact grout through grout ports in order to fill voids between the Final Shotcrete Lining and the Initial Shotcrete Lining/Waterproofing System.

E. Contact Grout: Cementitious Grout per Section 03 62 00, Non-shrink Grouting

F. Waste Shotcrete: Refer to Section 31 74 19.10, Initial Shotcrete Tunnel Lining.

G. Wavelength: Distance between two crests used in the determination of the smoothness of the final lining shotcrete surface.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Samples
   1. Submit for all lattice girders to be used:
      a. Two-foot long piece of the full cross-section and lacing - two samples.
      b. Butt plate splice and end plate mock-up.

C. Shop Drawings
   1. Shotcrete lining shop drawings indicating all structural and construction details and geometry including, but not limited to the following:
      a. Tolerances.
      b. Plan and sequence of lining installation.
   2. Lattice girder shop drawings, including specifications and fabrication details.

D. Product Information for each type of manufactured material and product indicated:
   1. Lattice Girders.
   2. Polypropylene Fibers.

E. Equipment
   1. Grouting Equipment: Submit product information for equipment and accessories used for contact grouting.

F. Contact Grouting Reports: The Contractor shall submit a contact grouting report for each cross passage addressing as a minimum the following:
1. Grouting duration, injection pressure, grout flow rate and injected grout quantity for each grout port.

2. Communication to other grout ports.

3. Calibration reports for grouting equipment used for grouting operation.

4. Test results for cement grout according to ASTM C109 for each cross passage

1.05 QUALITY ASSURANCE

A. Shotcrete:

1. Material and application specified in Section 31 74 19.05, Shotcrete for SEM Tunnels

2. Visual Inspection:
   a. Smoothness criteria: Do not exceed a depth to wavelength ratio of 1/100 measured with a 10-foot straight edge in the longitudinal direction and deviation from the theoretical curved surface in the circumferential direction.
   b. Thickness indicators: Install appropriate thickness indicators to verify lining thickness.

3. Sample coring and testing: Section 31 74 19.05, Shotcrete for SEM Tunnels.

4. Recording: for every application of shotcrete, record the following information into the daily shift report:
   a. Date, shift, tunnel temperature.
   b. Nozzleman.
   c. Test cylinders cast and cores drilled, including name of technician and sample identification.
   d. Results of visual inspection.
   e. Locations and volumes applied.

B. Lattice Girders:

1. Test lattice girders prior to the start of construction as follows:
   a. Three random samples of typical lengths to be installed, selected by the Resident Engineer.
   b. Provide manufacturer’s certification that lattice girders meet specified performance requirements.
   c. All lattice girders will be rejected if any one sample fails to meet specified requirements.
1.06 DELIVERY, STORAGE, AND HANDLING

A. General:

1. Load, transport, unload and store all structural materials so as to keep them clean and protected from damage.

2. Store cementitious materials in dry, protected enclosures and in accordance with manufacturer’s recommendation.

3. Store materials on platforms, skids or other supports above the ground surface.

4. Damaged materials to be clearly marked and removed from site immediately.

B. Lattice Girders:

1. Prevent bending, scraping, or overstressing members at all times.

2. Protect projecting parts vulnerable to bending or damage during handling.

3. Replace pieces bent or damaged unless repair is reviewed and accepted by the Resident Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Shotcrete: Use shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.

B. Lattice Girders:

1. For all lattice girders use three or four primary retaining bars connected by stiffening elements of the manufacturer’s design.

2. Design the lattice girder to allow shotcrete to penetrate into and behind the girder with a minimum of shotcrete shadowing.

3. Section Properties:

   a. As indicated on the Contract Drawings.

   b. A minimum of 5 percent of the moment of inertia shall be provided by the stiffening elements. This percentage will be calculated as an average along a repeatable length of the girder.

   c. The maximum centerline spacing of stiffening elements shall be no less than three times the height of the girder to ensure stability against buckling, with a tolerance of plus or minus 1 inch.

4. Material properties:

   a. Minimum physical properties of steel:

      1) Tensile Strength: 80 kilopounds per square inch (ksi) minimum.

      2) Yield Strength: 70 ksi minimum.
b. Construct the connection elements at the end of the girder of structural angle or plate meeting the minimum properties of ASTM A36.

5. Welding:
   a. Welding process to meet the requirements set forth by AWS for gas metal arc welding (GMAW). All welders: certified in accordance with AWS D1.1.
   b. Execute all welds parallel to the retaining bars with a minimum length of 1 inch.

C. Lattice Girder Accessories:
   1. Bolts: ASTM A325
   2. Butt and End Plates: Plate meeting the minimum properties of ASTM A36

D. Polypropylene Fibers: As specified in Section 03 24 00, Fibrous Reinforcing.

E. Membrane Waterproofing: As specified in Section 07 10 00, Waterproofing.

F. Contact Grout: In accordance with Section 03 62 00, Non-shrink Grouting.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Lattice Girders
   1. Install to conform to the shape of the final lining.
   2. Secure lattice girder segments by means of temporary tie rods or other means to maintain position during shotcreting. Do not damage or penetrate previously installed membrane waterproofing.
   3. Locate butt plates for lattice girder segment as shown on the Contract Drawings. Ensure tight connection of all elements.
   4. Remove all foreign material from splices prior to connection of subsequent lattice girder segment.

B. Shotcrete
   1. Obtain a signed statement for each cross passage from the Resident Engineer and waterproofing installer that membrane waterproofing system is free of defects prior to final shotcrete lining installation.
   2. Apply shotcrete as specified in Section 31 74 19.05, Shotcrete for SEM Tunnels.
   3. Do not use both wet-mix and dry-mix shotcrete in the Final Shotcrete Lining of any cross passage.
   4. Install shotcrete linings to provide thickness shown on the Contract Drawings. Use thickness indicators to ensure design thickness of shotcrete is applied.
   5. Remove all laitance, loose material, rebound, and Waste Shotcrete, and dispose in accordance with Section 01 74 01, Excavation Spoils and Muck Disposal.
6. Remove and respray shotcrete not meeting specified quality.

7. Trowel all shotcrete final linings to smoothness criteria indicated in Article 1.05 A.2.a, herein.

C. Contact Grouting: Perform contact grouting operation as follows and as indicated on the Contract Drawings:

1. Perform contact grouting through grout pipes in the final shotcrete lining with such quantity and pressure as to fill all voids. Maximum allowable grouting pressure for contact grouting shall not exceed 50 psi.

2. Pump grout until grout comes through adjacent grout pipes.

3. Do not inject grout into more than one hole simultaneously.

4. Any grout not injected within 90 minutes of completion of mixing shall be wasted.

5. Perform contact grouting behind the Final Shotcrete Lining only after it has gained its specified 28 day strength.

6. Perform contact grouting for each cross passage as a continuous operation.

D. Field Quality Control for Contact Grouting:

1. Grout Strength Tests: Take three 3-inch minimum diameter grout cubes and test in accordance with ASTM C109. Test as a minimum once per cross passage.

2. Grouting Equipment: Calibrate gages and meters of equipment used for contact grouting in the presence of the Resident Engineer prior to the start of contact grouting for each cross passage using master gages and meters.

END OF SECTION
SECTION 32 11 23
AGGREGATE BASE COURSES

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing, spreading, and compacting aggregate for aggregate base course as indicated.
B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work:
   1. Section 31 20 00, Earth Moving

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle (COS):
      a. Standard Specifications for Road, Bridge and Municipal Construction
      a. ASTM D2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
      b. ASTM D2922 Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)
      c. ASTM D3017 Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Material source, and all tests and certifications necessary to determine compliance with the specifications.
C. Test Reports: Submit plant and field test reports as specified in Articles 2.02 and 3.04 herein.

PART 2 - PRODUCTS

2.01 MATERIALS
1. Mineral Aggregate Type (No.): Type as indicated on the Contract Drawings. Conform to the COS Standard Specifications Section 9-03.
2.02 SOURCE QUALITY CONTROL
A. Perform sampling and tests of the aggregate base material in accordance with the COS Standard Specifications Section 9-03.15.

PART 3 - EXECUTION

3.01 EXAMINATION
A. Subgrade Examination
   1. Call for an inspection by the Resident Engineer and obtain written acceptance of the prepared subgrade before proceeding with the placement of aggregate base course.

3.02 PREPARATION
A. Perform subgrade preparation in accordance with the Contract Drawings and in close conformity with the lines, grades, and typical cross sections indicated, as referenced in a City of Seattle Standard Plan.
B. Subgrade preparation: Section 31 20 00, Earth Moving.

3.03 CONSTRUCTION
A. Place and compact aggregate base courses in accordance with the lines, grades, and typical cross sections indicated on the Contract Drawings, as referenced in a City of Seattle Standard Plan.
B. Construction requirements: COS Standard Specifications Section 4-04.3.

3.04 FIELD QUALITY CONTROL
A. Test for compliance with specified requirements for density and compaction of aggregate base specified in COS Standard Specifications Section 4-04.3(5) in accordance with ASTM D2922, and determine moisture-content compliance of the installed base course in accordance with ASTM D2216 and/or ASTM D3017 as determined by the Resident Engineer. Independently test each material type and/or when a material source changes.
B. Tolerances: Maximum allowable deviation in measured thickness of Aggregate Base Course surfacing is 1/2 inch less than specified depth.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing and placing Hot Mix Asphalt (HMA) on a prepared base in accordance with the lines, grades, thicknesses, and typical cross-sections shown on the Contract Drawings.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 31 20 00, Earth Moving
   2. Section 32 11 23, Aggregate Base Courses

1.02 REFERENCES

A. This Section incorporates by references the latest revision of the following documents.

B. City of Seattle (COS):
   1. Standard Specifications for Road, Bridge, and Municipal Construction
   2. Standard Plans for Municipal Construction

C. Seattle Department of Transportation (SDOT):
   1. Seattle Department of Transportation, Director’s Rule 2004-02: Street and Sidewalk Pavement Opening and Restoration

1.03 DEFINITIONS

A. Hot Mix Asphalt (HMA): A plant-mixed asphalt concrete pavement composed of asphalt binder and mineral aggregate mixed in specified proportions at a predetermined temperature to provide a homogenous, stable, workable, and compactable mixture.

B. Asphalt Treated Base (ATB): A dense-graded HMA consisting of a compacted course of base material which has been weatherproofed and stabilized by treatment with an asphalt binder.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Mix Design: Comply with the COS Standard Specification Section 5-04.3(6) for mix design submittal requirements.

C. Paving Plan for areas under traffic: COS Standard Specification Section 5-04.3(17).
D. Test Reports: Submit test results of sampling and testing, and inspection records within 24 hours of asphalt concrete placement.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Aggregates for Hot Mix Asphalt: COS Standard Specification Section 9-03.8.
C. Asphalt binder grade: PG 64-22 as defined in COS Standard Specification Section 9-02.1(4).
D. Tack Coat: CSS-1, CSS-1h, or STE-1 emulsified asphalt per COS Standard Specification Section 9-02.1(6).

2.02 MIXES

A. Mix Design for HMA including ATB: COS Standard Specification Section 5-04.3(6).
B. The nominal maximum aggregate size is as indicated on the Contract Drawings.
C. Asphalt binder: PG 64-22. The Contractor may propose the substitution of alternate grades of performance grade (PG) asphalt binder at no cost to Sound Transit as specified in COS Standard Specifications Section 5.04.2(1).

2.03 SOURCE QUALITY CONTROL

1. Acceptance Sampling and Testing of HMA: COS Standard Specifications Section 5-04.3(7)B.
2. Aggregates for ATB: Testing requirements of COS Standard Specification Section 9-03.6(3).
3. Aggregates for Hot Mix Asphalt: Test Requirements per COS Standard Specification Section 9-03.8(2).

PART 3 - EXECUTION

3.01 PREPARATION

A. Prepare subgrade for surfacing in accordance with Section 31 20 00, Earth Moving.
B. Construct Aggregate Base Course surfacing where indicated in accordance with Section 32 11 23, Aggregate Base Courses.
C. Surface Preparation of Existing Pavements:
   1. When an existing paved surface will be used as a base for one or more courses of asphalt concrete, 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 is to be placed or abutted per COS Standard Specifications Section 5-04.3(4)B4.

D. Surface preparation of aggregate bases or native subgrade: COS Standard Specifications Section 5-04.3(4)C.

3.02 CONSTRUCTION

A. Provide asphalt concrete pavement in accordance with the layout, configurations, and dimensions indicated on the Contract Drawings or in a referenced COS Standard Plan.

B. Construct HMA asphalt concrete pavement in conformance with the COS Standard Specifications Section 5-04.

C. Construct ATB in conformance with COS Standard Specification Section 4-06.

D. For asphalt concrete pavement patching within the City of Seattle right-of-way, comply with the SDOT Director’s Rule 2004-02: Street and Sidewalk Pavement Opening and Restoration.

3.03 FIELD QUALITY CONTROL

A. Compaction Requirements and Test Results for HMA: COS Standard Specifications Section 5-04.3(9)]. Include thickness of asphalt tested with each compaction report.

B. Compaction and Density for ATB per COS Standard Specification Section 4-06.3(7).


D. Surface Smoothness ATB: Final course of asphalt treated base shall not deviate at any point more than 3/8-inch from the bottom edge of a 10-foot straightedge laid on the surface in any direction.

E. Maintenance of Pavement

1. Allow newly compacted asphalt to cool to ambient temperature before any traffic is allowed on it. Do not allow traffic on the newly placed asphalt until approval has been obtained from the Resident Engineer.

2. Maintain finished pavement in finished clean condition until the work is accepted by the Resident Engineer.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for providing Portland cement concrete pavement for roadways, driveways, sidewalks, and concrete patching as indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 31 20 00, Earth Moving

2. Section 32 11 23, Aggregate Base Courses

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

1. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge and Municipal Construction
   b. Standard Plans for Municipal Construction

2. Seattle Department of Transportation
   a. SDOT Director’s Rule 2004-02: Street and Sidewalk Pavement Opening and Restoration

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit manufacturers' product data for proposed concrete admixtures.

C. Concrete Mix Designs: Submit mix designs as specified in City of Seattle Standard Specifications Section 5-05. Include Manufacturer's Certificate of Compliance indicating the batch weights and gradation reports of course and fine aggregates. Submit mix design to the Resident Engineer and include mix proportions per cubic yard, proposed sources, volume of entrained air, average 28 day Compressive Strength, water cement ratio, fineness modulus, and aggregate proportions.

D. Detectable warning plate for curb ramps: Submit the information required in COS Standard Specification Section 8-14.3(7)B to the Resident Engineer at least 5 Working Days in advance of placement.

E. Shop Drawings:
   1. Submit drawings showing the locations of all joints in concrete, including construction joints, expansion joints, isolation joints, and contraction joints.
2. Submit drawings indicating concrete placement method, sequence, location, and boundaries. Include each type and class of concrete, and quantity in cubic yards.

PART 2 - PRODUCTS

2.01 MATERIALS
A. Use materials in construction of cement concrete pavements, including but not limited to Portland cement, aggregates, reinforcing steel, curing materials and admixtures as specified in the COS Standard Specifications Section 5-05.2.

1. High-early-strength Portland cement concrete mixes may be used with approval from the Resident Engineer.

2.02 MIXES
A. Provide the class of concrete as indicated on the Contract Drawings. Provide a mix design for each class of concrete used. Proportion mixes as specified in COS Standard Specification Section 5-05.3(1).

B. Where class of concrete is not indicated on the Contract Drawings the following will apply in accordance with COS Standard Specification Section 5-05.3:

1. Concrete mix for arterial pavement: Roadway Cement Concrete, HES (1-1/2).

2. Concrete mix for residential streets and alleys: Roadway Cement Concrete, HES (1-1/2).

3. Portland cement concrete pavement patch: Cement Concrete Mix to allow for opening of traffic in 24 hours, HES (1-1/2).


C. Submit concrete mix designs to the Resident Engineer in advance of ordering, leaving sufficient review time as specified in Section 01 33 00, Submittal Procedures.

D. Concrete placeability, workability, and strength shall be the responsibility of the Contractor.

E. Nominal maximum size for concrete aggregate is defined as the smallest standard sieve opening through which the entire amount of the aggregate is permitted to pass.

2.03 SOURCE QUALITY CONTROL
A. Testing and Analysis:

1. Perform all testing and analysis of materials used in accordance with COS Standard Specifications Section 5-05 and Section 9.

PART 3 - EXECUTION

3.01 PREPARATION
A. Prepare subgrade for surfacing in accordance with Section 31 20 00, Earth Moving.
3.02 CONSTRUCTION

A. General

1. Construct Portland cement concrete pavement in accordance with the lines, grades, thicknesses, and typical cross-sections indicated on the Contract Drawings or in a referenced COS Standard Plan. Remove and replace pavement that is not within the allowable tolerances for line, grade, thickness and cross-section.

2. Construct Portland cement concrete pavements for roadways and pavement patching in accordance with the requirements of the COS Standard Specifications Section 5-05.3.

3. Construct Portland cement concrete sidewalks, and curb ramps in accordance with COS Standard Specifications Section 8-14.3.


5. Portland cement concrete pavement and sidewalk patching from trenching activities within the City right-of-way shall also comply with the City of Seattle’s Directors Rule: Street and Sidewalk Pavement Opening and Restoration.

3.03 FIELD QUALITY CONTROL:

A. Concrete Testing: Perform all acceptance testing of concrete pavement for roadways as specified in the COS Standard Specifications, Section 5-05.

B. Opening Pavements to Traffic:

1. Comply with the requirements for pavement opening specified in the COS Standard Specifications Section 5-05.3(17).

2. Do not open newly constructed pavements to traffic until the Resident Engineer has given approval.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 32 16 13
CONCRETE CURBS AND GUTTERS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing cement concrete curbs.

1.02 REFERENCES

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

1. American Society for Testing and Materials (ASTM)
   a. ASTM A 615, Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
   b. ASTM C143, Standard Test Method for Slump of Hydraulic-Cement Concrete
   c. ASTM C150, Standard Specification for Portland Cement
   d. ASTM C881, Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete

2. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge, and Municipal Construction
   b. Standard Plans for Municipal Construction

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Product Data: Submit manufacturers' product data for all materials being used.

C. Concrete Mix Design: Submit concrete mix design and test results.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Concrete for Extruded Concrete Curb: Minimum 28-day compressive strength of 2500 psi. Slump (ASTM C 143) not to exceed 1 inch. Maximum coarse aggregate 3/4 inch. Air-entrainment 5 percent plus or minus 1-1/2 percent.

B. Concrete for Cast-in-Place Curbs: Class 5 (3/4) in accordance with COS Specification Section 5-05. Slump not to exceed 3-1/2 inches.

C. Dowels and reinforcing steel: No 3 deformed steel billet bars, ASTM A 615, Grade 60.

D. Portland cement: Conform to the requirements of ASTM C150.

F. Bonding Material: Epoxy Bonding Agent meeting the requirements of COS Standard Specifications Section 9-26 and ASTM C881 for Type II epoxy resin.

G. Curing Compound: Type 1D, Class B, per COS Standard Specification Section 9-23.2.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General

1. Construct curbs in accordance with the layout, configurations, and dimensions indicated on the Contract Drawings or as referenced in a COS Standard Plan.

B. Extruded Cement Concrete Curbs

1. Place, shape and compact extruded cement concrete curb true to line and grade with an approved extrusion machine. Use an extrusion machine capable of shaping and thoroughly compacting the concrete to the required cross section.

2. Dry and clean pavement of loose or deleterious materials prior to curb placement. Anchor concrete curbs to the existing pavement using epoxy bonding agent. Place according to the recommendations of the bonding agent manufacturer.

3. Load the hopper of the curb machine with the homogenous mix. Run each hopper load of cement concrete through the curb laying machine, adjust it properly to form and compact the cement concrete mix for the curb.

4. Space joints in the extruded cement concrete curb at 15-foot intervals or to match existing transverse joints or cracks in existing pavement. Cut joints vertically.

5. Use Type1D, Class B liquid curing compound with pigment sufficient to make sprayed compound easily discernible.

6. Protect newly placed extruded cement concrete curb from traffic by barricades or other suitable means until it has attained its required strength of 2500 psi. Leave protection measures in place for at least 72 hours.

C. Cast-in-Place Curbs:


3.02 FIELD QUALITY CONTROL

A. Ensure that when checked with a 10-foot straightedge, grade does not deviate more than 1/8-inch, and alignment does not vary more than 1/4-inch.

END OF SECTION
SECTION 32 17 23
PAVEMENT MARKINGS

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing pavement marking as indicated

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle (COS)
      a. Traffic Control Manual for In-Street Work.
      c. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   2. Washington State Department of Transportation (WSDOT)
      a. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   3. Federal Highway Administration (FHA)
      a. Manual on Uniform Traffic Control Devices (MUTCD)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Submit to the Resident Engineer for approval, the respective manufacturers' product data for pavement marking materials.
C. Removal: Submit to the Resident Engineer for approval, the method(s) for removing existing and temporary pavement marking(s).

PART 2 - PRODUCTS

2.01 MATERIALS
A. For pavement marking 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 the applicable provisions of WSDOT 8-22, unless specified otherwise.
B. For pavement marking on streets, roadways, and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the materials used shall conform to
the applicable requirements of the jurisdictional agency’s standard drawings and specifications.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For pavement marking on Sound Transit owned streets, roadways, and parking lots, the work described in this Section shall be performed in accordance with the applicable provisions of WSDOT 8-22 unless specified otherwise.

B. For pavement marking on streets, roadways and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the work described in this Section shall be performed in accordance with the applicable requirements of the jurisdictional agency’s standard drawings and specifications.

C. Removal of pavement markings shall be performed by bead-blasting or other method approved by the Resident Engineer.

D. For existing pavement areas 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).

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for maintenance, support, and protection of existing underground utilities as indicated.

1.02 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.

B. Submit to Resident Engineer a schedule of estimated shut-down times coordinated with utilities.
   1. Obtain permission for shut-downs from utility owners and notify all interested parties, neighbors, utilities, and municipal and county authorities.
   2. Submit plan or schematic of temporary water or sewer services to the Resident Engineer for review and coordination with the utility owners.

PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 EXAMINATION
A. Field-locate existing utilities by contacting Call Before You Dig at 1 (800) 424-5555.
   1. For utility owners not covered by this telephone number, such as owners of non-pressurized sewer lines, Seattle Public Utilities, call the affected utility owners directly.

B. Ensure underground utilities are 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.
   1. Compare the field located utilities with the Contract Drawings. Notify Resident Engineer of discrepancies.

3.02 CONSTRUCTION
A. Do not operate, disconnect, or shut down any part of the existing utilities and services, except by permission of authorities having jurisdiction.

B. Notify Resident Engineer and affected utilities a minimum of 2 and a maximum of 10 working days before digging.

C. Do not remove utilities until shut-down time can be kept to a minimum.
D. Do not remove an existing utility line or service until the replacement line, crossover, or capping is ready to be performed.

E. Record locations of cuts, caps and utility abandonment on as-built drawing.

3.03 PROTECTION

A. Maintain existing utilities not indicated for removal or abandonment and protect from damage.

B. Maintain sewer manholes, water valves, meters, fire hydrants, and utility vaults accessible and keep clear of blockages from equipment, debris or construction material.

C. When existing utility services occupy the same trench space as a new utility, excavate to fully expose such services. Protect such services and work around them during excavation and new utility installation operations.

1. In the event of conflict with other underground utilities, immediately notify the Resident Engineer.

D. Provide shoring, underpinning, and structural support for existing utility lines and structures that become suspended or otherwise unsupported because of adjacent excavation operations.

E. If underground utilities are damaged in any way, notify the Resident Engineer and affected utility owners immediately for corrective action.

F. Contractor is responsible for all damage to existing utilities due to his operation and shall bear the cost to repair or replace the damaged utility.

END OF SECTION
SECTION 33 11 00
WATER UTILITY DISTRIBUTION PIPING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing water service supply mains, modifications to existing water mains, and services in City of Seattle Right-of-Way as indicated.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 45 00, Quality Control.
2. Section 01 77 00, Closeout Procedures.
3. Section 01 78 23, Operation and Maintenance Data.
4. Section 02 41 00, Demolition.
5. Section 31 23 19, Dewatering.
6. Section 31 23 33, Trenching and Backfilling.
7. Section 33 01 00, Operation and Maintenance of Utilities.

1.02 REFERENCES

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

1. American Water Works Association (AWWA):
   a. AWWA M41, Ductile Iron Pipe and Fittings
   b. AWWA M44, Distribution Valves: Selection, Installation, Field Testing, and Maintenance
   c. AWWA C104, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
   d. AWWA C110, Ductile-Iron and Gray-Iron Fittings for Water
   e. AWWA C111, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
   f. AWWA C115, Standard for Flanged Ductile-Iron Pipe with Threaded Flanges
   g. AWWA C151, Ductile-Iron Pipe, Centrifugally Cast, for Water
   h. AWWA C153, Ductile-Iron Compact Fittings for Water Service
i. AWWA C509, Resilient Seated Gate Valves for Water Service
j. AWWA C600-05, Installation of Ductile-Iron Water Mains and Their Appurtenances
k. AWWA C651, Disinfecting Water Mains

2. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge and Municipal Construction
   b. Standard Plans for Road, Bridge and Municipal Construction

   a. NFPA 24, Standard for the Installation of Private Fire Service Mains and their Appurtenances

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Include data on pipe, fittings, and appurtenances including manufacturer’s recommendations for pipe installation.
C. Lay plans for the pipeline construction. Include details for each connection to an existing main. The review of this submittal by the Resident Engineer, Water District, and municipal and county authorities does not relieve the Contractor of his responsibilities to any damage on existing utilities due to his operation in accordance with Section 33 01 00, Operation and Maintenance of Utilities.
D. General: Refer to Section 01 77 00, Closeout Procedures, and 01 78 23, Operation and Maintenance Data, for submittal requirements and procedures.
E. Record Documents: Show actual locations of piping mains, valves, connections, and depths of burial on the as-built drawings in accordance with Section 01 78 39, Project Record Documents for review.
F. Construction Work Plan: Submit a construction work plan in accordance with requirements of Section 01 45 00, Quality Control. An approved Construction Work Plan is a precondition for the Readiness Review Meeting.

1.04 QUALITY ASSURANCE
A. Regulatory Requirements:
   1. Private Property: Comply with City of Seattle Fire Department standards for water service piping, appurtenances, installation, and testing.
   2. City Right-of-Way: Comply with City of Seattle, Seattle Public Utilities standards for water service piping, appurtenances, installation, and testing.
B. Provide piping materials that have been stamped or marked with the specified testing agency.
D. NFPA Compliance: Comply with NFPA 24 for materials, installations, test, flushing, and valve and hydrant supervision for fire-service-main piping for fire suppression.

1.05 DELIVERY, STORAGE, AND HANDLING

A. Deliver piping 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. Inspection: Inspect pipe before it is installed. Remove defective products from the Project Site.

1.06 PROJECT CONDITIONS

A. Sequencing and Scheduling: Include sequencing and scheduling information in the Construction Work Plan, refer to Article 1.03F, herein.

PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Install only new materials for water distribution and transmission. Materials used for temporary Water Main and for temporary service connection purposes may be either new or previously used materials and are subject to the Resident Engineer’s inspection and approval prior to installation. Verify all direct and indirect drinking water system components which come in contact with potable water have National Sanitation Foundation certification.

B. Ductile Iron Pipe and Fittings

1. Ductile Iron pipe: Centrifugally cast in 18-feet nominal lengths marked conforming to AWWA C151.

   a. Cement-mortar lining conforming to AWWA C104.
   b. Standard Thickness Class 52.
   c. For non-restrained joints, use rubber gasket, push-on type, or mechanical joints conforming to AWWA C111.

2. Fittings for Ductile Iron Pipe: Ductile Iron conforming to AWWA C110, and AWWA C111, or AWWA C153 and cement-mortar lined conforming to AWWA C104.

   a. Use mechanical joint fitting joints except where restrained joint systems are required.
   b. Where restrained joint pipe is required, use threaded flanges by restrained joint adapters no longer than three pipe diameters. Threaded flanges and pipe conforming to AWWA C115. Seal the exterior flange lip overlapping the pipe barrel with bituminous mastic.
   c. The minimum length for sleeves less than or equal to 12 inches in diameter is 12 inches. Provide mechanical joint sleeves.
   d. Join the pipe with a mechanical joint sleeve where ductile iron pipe is to be joined to existing cast iron pipe of the same nominal size and the outside diameter of the existing cast iron pipe varies 0.05 inch or less from the specified outside diameter of the ductile iron pipe being joined.
e. Join the pipe with a transition mechanical joint sleeve having a single-piece body where 8 inch or smaller diameter ductile iron pipe is to be joined to existing cast iron pipe of the same nominal size and the outside diameter of the existing cast iron pipe conforms to the 1908 AWWA classifications of A, B, C, D, E, or F.

f. Hub-by-flange fitting length: conform to AWWA C110 or AWWA C153, and be a single-piece casting. Do not use threaded pipe and flange combinations.

3. Restrained Joints: Boltless design which is flexible after assembly and can be disassembled without special tools, such as TR Flex Restrained Joint Pipe as manufacturer by U.S. Pipe Co., or approved equal. Joint to have a positive metal to metal contact locking system without the use of gripping teeth and the joint restraint system for the pipe must be the same as the joint restraint system for the pipe fittings.


5. Insulating couplings: Insulating couplings and flange kits are required at any point of connection of two dissimilar metallic material pipes (i.e., ductile iron to cast iron). Requirements per COS Standard Specification Section 9-30.2(7)A.


D. Gate Valves: Resilient seated gate valves per AWWA C509. Valves to have name or mark of the manufacturer, year valve casting was made, size, and working pressure plainly cast in raised and legible letters on the valve body. Valves to be NSF approved and have ductile iron bodies. Valves to be stamped with “NSF APPROVED” and “DI”.

E. Valve Boxes: COS Standard Specification Section 9-30.3(5).

F. Concrete Thrust Blocking: Constructed of Class 5 (1-1/2) concrete per COS Specification Section 5-05.3.

2.02 SOURCE QUALITY CONTOL

A. Water Main material to be used in City of Seattle Right-of-Way is subject to pre-installation taste and odor testing requirements in accordance with COS Standard Specification Section 7-11.2(2).

PART 3 - EXECUTION

3.01 PREPARATION

A. Coordinate the installation of the water distribution system with other utilities to avoid conflicts.

B. Trench, Bed and Backfill as specified in Section 31 23 33, Trenching and Backfilling.

C. Provide safety systems for trench excavation as specified in Section 31 23 33, Trenching and Backfilling.
D. Trench dewatering as specified in Section 31 23 19 Dewatering. Continue trench dewatering until the ends of the pipe are sealed and provisions are made to prevent floating of the pipe. Prevent trench water or other deleterious materials from entering the pipe at any time.

E. Support and protect existing utilities as specified in Section 33 01 00, Operation and Maintenance of Utilities.

F. Abandon and remove existing water mains indicated for removal or abandonment as specified in Section 02 41 00, Demolition.

G. Pipe handling requirements in accordance with COS Standard Specification Section 7-11.3(2).

H. Protection:
   1. Prevent water from entering trenches and excavations.
   2. Other than chlorination chemicals and clean water, place nothing inside pipes and fittings.
   3. Fit expansion plug into open end of pipe joints being laid. Allow plug to remain in-place when pipe laying is not in progress; remove plug when pipe laying is resumed. Protect mouth of pipe being laid in rock.
   4. Protect exposed, installed pipe from damage and flooding.
   5. Keep installed pipe clean until work has been accepted.
   6. Protect pipe coatings from damage during storage and installation.

3.02 CONSTRUCTION

A. Construct the water distribution system in accordance with AWWA C600 and AWWA M41.

B. Water distribution systems installed in the City of Seattle Right-of-Way shall comply with COS Standard Specification Section 7-11.3.

C. Installing Restrained Joint Pipe: Fully extend restrained joint pipe by pulling on the joint after the installation of the pipe segments as recommended by the manufacturer of the restrained joint pipe. Bending or Bucking of the pipe when the pipe is charged will not be accepted. Submit the restrained joint manufacturer’s recommendations for pipe installation to the Resident Engineer at least 5 working Days prior to installation.

D. Cutting of Restraint Joint Pipe: Cut in accordance with the pipe manufacturer’s recommendations. Submit to the Resident Engineer at least 2 Working Days in advance, the pipe manufacturer’s recommendation for cutting restrained joint pipe including the Manufacturer’s Certificate of Compliance stating the cutting process does not adversely impact the pipe material or integrity of the joint.

E. Installing Pipe on Curves: On long radius curves, either horizontal or vertical, pipe may be installed with standard pipe by deflecting the joints. Do not exceed the manufacturer’s printed recommended deflection at each pipe joint when pipe is installed on a horizontal or vertical curve. Submit to the Resident Engineer the pipe manufacturer’s joint deflection recommendations prior to pipe installation indicating deflections are within allowable AWWA specification tolerances.
F. AWWA Gate Valves: Comply with AWWA C600 and AWWA M44. Install each underground valve with stem pointing up and with valve box.

G. Minimum depth of cover over the pipe is 36 inches.

H. Concrete Thrust Blocking: City of Seattle Specification Section 7-11.3(13).

I. After all tests, flushing, and disinfection have been successfully completed and the installed water main and appurtenances have been approved by the Resident Engineer, make requests for shutdowns for connections at least 5 Working Days in advance of the desired shutdown.

J. Connections for City of Seattle owned Water Mains: Comply with all paragraphs of COS Standard Specifications Section 7-11.3(9).

3.03 FIELD QUALITY CONTROL

A. Testing of City of Seattle owned Water Mains and appurtenances shall be in accordance with the COS Standard Specifications.


END OF SECTION
SECTION 33 30 00
SANITARY SEWERAGE UTILITIES

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for providing the sanitary sewerage and combined sewerage systems and connection to the existing sanitary and combined sewer systems as indicated, temporary bypasses, utility support system, including but not limited to pipes, manholes, and the related cast iron and steel products required for covers and manhole steps and ladders.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.

1. Section 01 78 39, Project Record Documents
2. Section 02 41 00, Demolition
3. Section 31 23 19, Dewatering
4. Section 31 23 33, Trenching and Backfilling
5. Section 31 50 00, Excavation Support and Protection

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

1. American Water Works Association (AWWA):
   a. AWWA C104, Cement-Mortar Lining for Ductile-Iron Pipe and Fittings for Water
   b. AWWA C111, Rubber-Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
   c. AWWA C150, Standard for Thickness Design of Ductile-Iron Pipe
   d. AWWA C151, Ductile-Iron Pipe, Centrifugally Cast, for Water
   e. AWWA C900, Standard for Polyvinyl Chloride Pressure Pipe and Fabricated Fittings

2. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge, and Municipal Construction
   b. Standard Plans for Municipal Construction
1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Certification: Submit a Manufacturer’s Certificate of Compliance, based on the manufacturer’s routine quality control tests showing that the pipe meets or exceeds the requirements of the pertinent ASTM, ANSI, or AWWA specification.

C. Submit to the Resident Engineer, for review, a written proposal for temporary sewer bypasses including a list of all equipment being used. Submit at least 10 Working Days in advance of scheduled work. The Resident Engineer’s review does not relieve the Contractor of its responsibilities or of any public liability for sewage spills.

D. Structural Engineer’s Qualifications: For Contractor-designed utility support systems, submit qualifications of design engineer demonstrating similar recent design experience.

E. Working Drawings: For the utility support system designed by the contractor, submit Working Drawings signed and sealed by a structural engineer currently registered in the State of Washington. Design the support system to conform to the City of [Seattle] Building code and the seismic design criteria indicated in the Contract Drawings. Include the following in the Working Drawings:
   1. Element sizes and locations
   2. Element assembly and connection details
   3. Interfacing details for adjacent construction elements

F. Calculations: For the utility support system designed by the Contractor, submit calculations to support the design shown on the Working Drawings. Ensure calculations are signed and sealed by a structural engineer currently registered in the State of Washington.

G. Record Documents: Show actual locations of piping mains, connections, and pipe inverts at manholes on as-built drawings in accordance with Section 01 78 39, Project Record Documents, for review.

1.04 QUALITY ASSURANCE

A. Structural Engineer: For contractor-designed utility support systems, select a licensed structural engineer currently registered in the State of Washington, with a minimum of 5 years of experience in the design and construction of utility support systems or similar systems.

1.05 DESIGN CRITERIA FOR UTILITY SUPPORT

A. Design and maintain utility support system so that the vertical deflection of the utility does not exceed 3/4 inch over 48 feet more or less than the design grade specified in the Contract Drawings.

B. Design utility support system with allowances for eccentricities resulting from the misalignment of framing elements.

C. Design utility support system to allow in the field and periodic adjustment to remediate unacceptable vertical deflections.

D. Ensure that connections of the utility support system to any adjacent structural element, such as shoring walls or station excavation structural elements, does not compromise the strength of those structures.
PART 2 - PRODUCTS

2.01 MATERIALS

A. General:
   1. Install only new materials. Materials used for temporary purposes may be either new or previously used materials and are subject to the Resident Engineer’s inspection and approval prior to installation.

B. Pipe, fittings, and joints: Pipe type used for sanitary, combined and side sewers is as specified on the Contract Drawings.
   1. Restrained Joint Ductile Iron Pipe and Fittings:
      a. Ductile Iron Pipe conforming to AWWA C151.
      b. Push-on joints conforming to AWWA C111.
      c. Double thickness (one-eighth inch) cement mortar lined in accordance with AWWA C104.
      d. Thickness Class 20 in accordance with AWWA C150.
      e. Restrained Joint pipe and fittings: Boltless design which is flexible after assembly and can be disassembled without special tools, such as TR Flex Restrained Joint Pipe as manufactured by U.S. Pipe Co., or approved equal. Joint to have a positive metal to metal contact locking system without the use of gripping teeth and the joint restraint system for the pipe must be the same as the joint restraint system for the pipe fittings.

2. Polyvinyl Chloride (PVC) Pipe for gravity sewer: Pipe, fittings and joints in accordance with AWWA C900, Pressure Class 100.

C. Precast Manholes: in accordance with the COS Standard Plan number noted on the Contract Drawings and as specified in Section 7-05.2 of the COS Standard Specifications.


E. Manhole Ring and Cover: COS Standard Specifications Section 9-12.8.


PART 3 - EXECUTION

3.01 PREPARATION

A. Notify Resident Engineer at least 20 days prior to beginning Work associated with the new or existing sanitary/combined sewer system. In addition to the Resident Engineer’s inspection, SPU will provide its own inspection services for the Work associated with the sanitary/combined sewer systems within City Right-of-Way. COS Department of Planning and Development will inspect side sewer replacements and connections before reactivation. Provide side sewer as-built drawings to COS Department of Planning and Development in accordance with their standards.
B. Inspection: Inspect pipe before it is installed. Remove defective products from the Project Site.

3.02 CONSTRUCTION

A. Pipe Trenching, Bedding, and backfilling are specified in Section 31 23 33, Trenching and Backfilling.

B. Pipe abandonment and removals are specified in Section 02 41 00, Demolition.

C. Dewatering: Keep excavations free of water during excavation, installation of pipeline, and placement of bedding and trench backfill. Control surface run-off so as to prevent entry or collection of water in excavations. Dewater excavations containing water per the requirements of Section 31 23 19, Dewatering.

D. Trench Safety and Support Systems: Where trench excavation is deeper than 4 feet, construct and maintain safety systems that meet the requirements of the Washington Administrative Code (WAC) Chapter 296-155 Part N. Comply with the requirements of Section 31 50 00, Excavation Support and Protection.

E. Design and install a utility support system to support and protect the 8-inch sanitary sewer which crosses over the Roosevelt Station excavation. This support system will be left in place to continue supporting the pipe at the end of the Contract.

F. Monitor structurally supported sewer for movement throughout the project duration. Notify Resident Engineer and implement remedial measures if movement exceeds the maximum allowable amount specified in Article 1.05A.

G. Pipe installation: COS Standard Specification Section 7-17.3(2).

H. Install manholes, re-channel existing manholes, make manhole pipe connections, and connections to existing manholes in accordance with the City of Seattle Standard Specifications Section 7-05.3.

I. Temporary Sewer Bypass: Install a temporary bypass to maintain uninterrupted Sewer service. Install a bypass system that diverts the effluent flow at an upstream access manhole and pump it through a separate conduit to a downstream reentry point or to an adjacent Sewer system. Size the pump and bypass conduit to adequately handle the flow. Size to ensure that the effluent level in the bypass pumping manhole does not rise more than 1 foot above the crown of the lowest incoming Sewer pipe.

J. When connecting new pipe to existing pipe where materials differ, use only new pipe having the same inside diameter as the existing. Match inverts, grade, and alignment. Connect joints between pipes with a mismatched wall thickness with a flexible gasketed coupling, adapter or coupling-adapter to make a watertight joint.

K. Leave side sewer connections and sewer mains uncovered until the Resident Engineer has inspected and approved the work.

3.03 FIELD QUALITY CONTROL

A. Notice of Testing

1. Notify the Resident Engineer at least 2 Working Days before testing. Perform all testing in the presence of the Resident Engineer.

B. Cleaning and Testing:
1. Clean pipes and manholes and perform testing as specified in the COS Standard Specification Section 7-17.3(4).

2. Furnish, install, and operate pumps, gages, meters, and individual pipe connections for testing.

C. Television Inspection

1. Videotape the interior of all newly installed sewer pipes 6 inches through 48 inches to determine the acceptance of the Work. Perform television inspection work in accordance with the City of Seattle Standard Specifications Section 7-17.3(4).
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for providing the storm water drainage system and connection to storm drainage mains as indicated, including but not limited to drainage pipes, culverts, related drainage structures, trench drains, catch basins, drainage inlets, storm manholes, and the related cast iron and steel products required for gratings, covers, and manhole steps and ladders.

B. Related Sections: The work of the following Sections is related to the work of this Section. Other Sections, not referenced below, may also be related to the proper performance of this work.
   1. Section 02 41 00, Demolition.
   2. Section 31 23 33, Trenching and Backfilling
   3. Section 31 50 00, Excavation Support and Protection
   4. Section 33 30 00, Sanitary Sewerage Utilities

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle (COS):
      a. Standard Specifications for Road, Bridge and Municipal Construction
      b. City of Seattle Standard Plans for Municipal Construction

1.03 DEFINITIONS

A. COS Standard Specifications: City of Seattle Standard Specifications for Road, Bridge and Municipal Construction

B. COS Standard Plans: City of Seattle Standard Plans for Municipal Construction

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.

B. Certification: Submit certification or other acceptable evidence that the following meet the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction.
   1. Pipe
   2. Jointing
PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe

1. Pipe used for storm drains is as specified or herein:
   a. Flexible Pipe Material:
      1) Polyvinyl Chloride (PVC)
      2) Corrugated Metal
      3) Polyethylene (PE)
   b. Rigid Pipe Material:
      1) Concrete
      2) Ductile Iron

2. Meet the requirements of the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-05, Pipe.
   a. Clearly mark all pipe with type, class, date of manufacturer, location of manufacturing plant and thickness. Lettering: Legible and permanent under normal conditions of handling and storage.
   b. Design pipe exterior loading strength and bedding to accommodate construction and permanent loading.

B. Jointing: Provide jointing material from same material as pipes and in accordance with the manufacturer's recommendations. Meet the requirements of the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-05.

C. Catch Basins and Manholes: Use type as indicated on the Contract Drawings and in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-12.

D. Frame and Grate: Use cast iron in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-12.

E. Flexible Couplings: Use type as indicated on the Contract Drawings and/or in accordance with the City of Seattle Standard Specifications.
F. Manhole Steps, Handholds, and Ladders: Use type as indicated on the Contract Drawings and/or in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 9-12.

PART 3 - EXECUTION

3.01 PREPARATION

A. Existing storm sewer systems shown on the plans to be abandoned and/or removed shall be abandoned and/or removed in accordance with Section 02 41 00, Demolition.

3.02 CONSTRUCTION

A. Excavate trenches, and place pipe bedding backfill for utility burial in accordance with to Section 31 23 33, Trenching and Backfilling and Section 31 50 00, Excavation Support and Protection.

B. Follow the specifications of the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 7-17.3 and Section 7-08.3(2) for the construction and installation requirements for the pipe, related structures, and other incidental work.

C. Maintain uninterrupted service with temporary storm sewer bypass as depicted on the Contract Drawings, when construction work will interfere with storm water flow in the existing sewer. Install Temporary Sewer Bypass in accordance with the City of Seattle Standard Specifications, Section 7-17.3(2) K.

D. Remove and/or abandon existing Storm Drain System as depicted in the Contract Drawings, in accordance with Section 02 41 00, Demolition.

E. Keep excavations free of water during excavation, installation of pipeline, and placement of bedding and trench backfill. Control surface run-off so as to prevent entry or collection of water in excavations. Dewater excavations containing water per the requirements of Section 31 23 19, Dewatering.

F. Where trench excavation is deeper than 4 feet, construct and maintain safety systems that meet the requirements of the Washington Administrative Code (WAC) Chapter 296-155 Part N. Comply with the requirements of Section 31 50 00, Excavation Support and Protection.

G. Where storm drains are temporarily cut or plugged, temporary mitigation is to be provided, including pumping storm water if required to maintain uninterrupted storm drainage service.

3.03 FIELD QUALITY CONTROL

A. Clean and test pipelines and appurtenances within 15 working days after backfilling of pipelines and structures. Test pipe for leakage after installation in accordance with the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 7-17.3(4).

B. TV Inspection: Videotape the interior of all storm pipes 6 inches through 48 inches to determine the acceptance of this portion of the Work. Follow the City of Seattle Standard Specifications for Road, Bridge and Municipal Construction, Section 7-17.3(4) I for the TV inspection work.

C. Provide as-built surveys of all new storm drainage system.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes modifications to any traffic signal system, as specified herein or as directed by Resident Engineer.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. City of Seattle (COS)
      a. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.
   2. Washington State Department of Transportation (WSDOT)
      a. Standard Specifications for Road, Bridge, and Municipal Construction, including applicable provisions relating to delivery of maintenance and operations manuals, warranties, and acceptance testing.

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Submit plan for modifying traffic signal system to the Resident Engineer and City of Seattle for review and approval.

PART 2 - PRODUCTS

A. Equipment
   1. For traffic signals on streets, roadways, and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the materials used shall conform to the applicable requirements of the jurisdictional agency’s standard drawings and specifications.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For traffic signals on Sound Transit owned streets, roadways, and parking lots, the work described in this Section shall be performed in accordance with the applicable provisions of WSDOT 8-20 unless specified otherwise.

B. For traffic signals on streets, roadways and parking areas that are to be owned or maintained by jurisdictions other than Sound Transit, the work described in this Section shall be performed in accordance with the applicable requirements of the jurisdictional agency’s standard drawings and specifications.

C. Coordinate with City of Seattle for modification to traffic signal systems.

END OF SECTION