UNIVERSITY LINK LIGHT RAIL

IFB NO. RTA/LR 95-10

CONTRACT U250
UW STATION FINISHES

VOLUME 2
BOOK 2 OF 2

CONTRACT SPECIFICATIONS
100% SUBMITTAL

MAY 2009

PREPARED BY:

[Logo]

Northlink Transit Partners
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**Appendix A – Geotechnical Conditions Summary**

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COMMON WORK RESULTS FOR PLUMBING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for materials and installation common to most piping systems including dielectric fittings, mechanical sleeve seals, sleeves, escutcheons, grout, equipment, concrete bases, and supports and anchorages.

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 05 50 00, Metal Fabrications.
3. Section 07 84 00, Firestopping.

1.02 REFERENCES

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

1. American Society of Mechanical Engineers (ASME)
   a. ASME B1.20.1 Pipe Threads, General Purpose (Inch)

   a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   b. ASTM B32 Standard Specification for Solder Metal
   c. ASTM B813 Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
   d. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
   e. ASTM C1107 Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
   f. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120
   h. ASTM D2261 Standard Test Method for Tearing Strength of Fabrics by the Tongue (Single Rip) Procedure (Constant-Rate-of-Extension Tensile Testing Machine)

j. ASTM D2657 Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings

k. ASTM D2672 Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement


m. ASTM D2855 Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings

n. ASTM D3138 Standard Specification for Solvent Cements for Transition Joints Between Acrylonitrile-Butadiene-Styrene (ABS) and Poly(Vinyl Chloride) (PVC) Non-Pressure Piping Components

o. ASTM D3139 Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals


3. American Welding Society (AWS)

a. AWS A5.8 Specification for Filler Metals for Brazing and Braze Welding

b. AWS D1.1 Errata for Structural Welding Code – Steel

c. AWS D10.12 Guide for Welding Mild Steel Pipe

1.03 DEFINITIONS

A. Finished Spaces: Spaces other than plumbing and electrical equipment rooms, furred spaces, pipe chases, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspaces, and tunnels.

B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and plumbing equipment rooms.

C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in chases.

E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
1.04 SUBMITTALS

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

B. Electrical Characteristics for Plumbing Equipment: Equipment of higher electrical characteristics may be furnished provided such proposed equipment is approved in writing and connecting electrical services, circuit breakers, and conduit sizes are appropriately modified. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe, Tube and Fittings

1. Refer to individual Division 22, Plumbing, piping Sections for pipe, tube, and fitting materials and joining methods.

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

B. Joining Materials

1. Refer to individual Division 22, Plumbing, piping Sections for special joining materials not listed below.

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

3. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.


5. Brazing Filler Metals: AWS A5.8, BCP Series or BAg1, unless otherwise indicated.

6. Solvent Cements for Joining Plastic Piping:
   a. CPVC Piping: ASTM F 493.
   b. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

C. Dielectric Fittings

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

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

3. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 degrees F.

4. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig minimum working pressure as required to suit system pressures.
5. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 degrees F.

6. 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

1. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

2. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

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

4. 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. Galvanized-Steel Sheet: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

2. Steel Pipe: ASTM A 53, Type E, Grade B, Schedule 40, galvanized, plain ends.

3. Cast Iron: Cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.

4. Molded PVC: Permanent, with nailing flange for attaching to wooden forms.

5. PVC Pipe: ASTM D 1785, Schedule 40.

6. Molded PE: Reusable, PE, tapered-cup shaped, and smooth-outer surface with nailing flange for attaching to wooden forms.

F. Escutcheons

1. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.

2. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.

3. One-Piece, Cast-Brass Type: With set screw.


5. Split-Casting, Cast-Brass Type: With concealed hinge and set screw.

G. Grout
1. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.
   
   
   b. Design Mix: 5000-psi, 28-day compressive strength.
   
   c. Packaging: Premixed and factory packaged.

PART 3 - EXECUTION

3.01 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.

3.02 INSTALLATION

A. Piping Systems

1. Install piping according to the following requirements and Division 22, Plumbing, Sections specifying piping systems.

2. Contract Drawings, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

3. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.

4. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

5. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

6. Install piping to permit valve servicing.

7. Install piping at indicated slopes.

8. Install piping free of sags and bends.

9. Install fittings for changes in direction and branch connections.

10. Install piping to allow application of insulation.
11. Select system components with pressure rating equal to or greater than system operating pressure.

12. Install escutcheons for penetrations of walls, ceilings, and floors.

13. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs.

   a. Install steel pipe for sleeves smaller than 6 inches in diameter.
   b. Install cast-iron "wall pipes" for sleeves 6 inches and larger in diameter.
   c. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

15. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   a. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

16. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Refer to Section 07 84 00, Firestopping, for materials.

17. Verify final equipment locations for roughing-in.

18. Refer to equipment specifications in other Sections herein 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.
3.03 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. Place grout, completely filling equipment bases.
6. Place grout on concrete bases and provide smooth bearing surface for equipment.
7. Place grout around anchors.
8. Cure placed grout in accordance with manufactures recommendations.

3.04 CONSTRUCTION

A. Piping Joint

1. Join pipe and fittings according to the following requirements and Division 22. Plumbing, Sections specifying piping systems.
2. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
3. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
6. 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.
7. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to Part 1 "Quality Assurance" Article.
8. Flanged Joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

9. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
   a. Comply with ASTM F 402, for safe-handling practice of cleaners, primers, and solvent cements.
   b. ABS Piping: Join according to ASTM D 2235 and ASTM D 2661 Appendixes.
   c. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
   d. PVC Pressure Piping: Join schedule number ASTM D 1785, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule-number PVC pipe and socket fittings according to ASTM D 2855.
   e. PVC Nonpressure Piping: Join according to ASTM D 2855.
   f. PVC to ABS Nonpressure Transition Fittings: Join according to ASTM D 3138 Appendix.


12. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   a. Plain-End Pipe and Fittings: Use butt fusion.
   b. Plain-End Pipe and Socket Fittings: Use socket fusion.

B. Piping connections
1. Make connections according to the following, unless otherwise indicated:
   a. Install unions, in piping 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. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.
   d. Wet Piping Systems: Install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

C. Concrete Bases
1. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer’s written instructions and according to seismic codes at Project.
   a. Construct concrete bases of dimensions indicated, but not less than 4 inches larger in both directions than supported unit.
b. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of the base.

c. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.

d. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.

e. Install anchor bolts to elevations required for proper attachment to supported equipment.

f. Install anchor bolts according to anchor-bolt manufacturer's written instructions.

g. Use 3000-psi, 28-day compressive-strength concrete and reinforcement as specified in Section 03 05 15, Portland Cement Concrete.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for thermometers and gages.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. ASME B40.3 Bimetallic Actuated Thermometers
      b. ASME B40.5 Snubbers
      c. ASME B40.100 Pressure Gauges and Gauge Attachments
   2. 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

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data for each type of product indicated.

PART 2 - PRODUCTS

2.01 METAL-CASE, LIQUID-IN-GLASS THERMOMETERS
A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Contract Drawings or comparable product by one of the following:
   1. Palmer - Wahl Instruments Inc.
   2. Trerice, H. O. Co.
   3. Weiss Instruments, Inc.
   4. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
B. Case: Brass, 7 inches long.
C. Tube: Red or blue reading, mercury or organic-liquid filled, with magnifying lens.
D. Tube Background: Satin-faced, nonreflective aluminum with permanently etched scale markings.
E. Window: Glass.
F. Connector: Adjustable type, 180 degrees in vertical plane, 360 degrees in horizontal plane, with locking device.
G. Stem: Copper-plated steel, aluminum, or brass for thermowell installation and of length to suit installation.
H. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

2.02 BIMETALLIC-ACTUATED DIAL THERMOMETERS

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Contract Drawings or comparable product by one of the following:

2. Ernst Gage Co.
3. Eugene Ernst Products Co.
5. Miljoco Corp.
6. NANNMAC Corporation.
7. Noshok, Inc.
8. Palmer - Wahl Instruments Inc.
9. REO TEMP Instrument Corporation.
10. Tel-Tru Manufacturing Company.
11. Trrice, H. O. Co.
12. Weiss Instruments, Inc.
13. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
14. WIKA Instrument Corporation.
15. Winters Instruments.

B. Description: Direct-mounting, bimetallic-actuated dial thermometers complying with ASME B40.3.
C. Case: Liquid-filled type, stainless steel with 5-inch diameter.
D. Element: Bimetal coil.
E. Dial: Satin-faced, nonreflective aluminum with permanently etched scale markings.

F. Pointer: Red metal.

G. Window: Glass.

H. Ring: Stainless steel.

I. Connector: Adjustable angle type.

J. Stem: Metal, for thermowell installation and of length to suit installation.

K. Accuracy: Plus or minus 1 percent of range or plus or minus 1 scale division to maximum of 1.5 percent of range.

2.03 THERMOWELLS

A. Manufacturers: Same as manufacturer of thermometer being used.

B. Description: Pressure-tight, socket-type metal fitting made for insertion into piping and of type, diameter, and length required to hold thermometer.

2.04 PRESSURE GAGES

A. Basis-of-Design Product: Subject to compliance with requirements, provide product indicated on Contract Drawings or comparable product by one of the following:

1. AMETEK, Inc.; U.S. Gauge Div.
3. Ernst Gage Co.
4. Eugene Ernst Products Co.
5. KOBOLD Instruments, Inc.
7. Miljoco Corp.
8. Noshok, Inc.
10. REO TEMP Instrument Corporation.
11. Trerice, H. O. Co.
12. Weiss Instruments, Inc.
13. Weksler Instruments Operating Unit; Dresser Industries; Instrument Div.
14. WIKA Instrument Corporation.
15. Winters Instruments.

B. Direct-Mounting, Dial-Type Pressure Gages: Indicating-dial type complying with ASME B40.100.
1. Case: Liquid-filled type, drawn steel or cast aluminum, 6-inch diameter.
2. Pressure-Element Assembly: Bourdon tube, unless otherwise indicated.
3. Pressure Connection: Brass, NPS 1/4, bottom-outlet type unless back-outlet type is indicated.
4. Movement: Mechanical, with link to pressure element and connection to pointer.
7. Window: Glass.
9. Accuracy: Grade A, plus or minus 1 percent of middle half scale.
10. Vacuum-Pressure Range: 30-in. Hg of vacuum to 15 psig of pressure.
11. Range for Fluids under Pressure: Two times operating pressure.

C. Pressure-Gage Fittings:
   1. Valves: NPS 1/4 brass or stainless-steel needle type.
   2. Snubbers: ASME B40.5, NPS 1/4 brass bushing with corrosion-resistant, porous-metal disc of material suitable for system fluid and working pressure.

PART 3 - EXECUTION

3.01 THERMOMETER APPLICATIONS
   A. Install liquid-in-glass thermometers in the outlet of each domestic, hot-water storage tank.
   B. Install liquid-filled-case-type, bimetallic-actuated dial thermometers at suction and discharge of each pump.
   C. Provide the following temperature ranges for thermometers:
      1. Domestic Hot Water: 30 to 180 degrees F, with 2-degree scale divisions.
      2. Domestic Cold Water: 0 to 100 degrees F, with 2-degree scale divisions.

3.02 GAGE APPLICATIONS
   A. Install dry-case-type pressure gages for discharge of each pressure-reducing valve.
   B. Install liquid-filled-case-type pressure gages at suction and discharge of each pump.

3.03 INSTALLATIONS
   A. Install direct-mounting thermometers and adjust vertical and tilted positions.
   B. Install thermowells with socket extending a minimum of 2 inches into fluid and in vertical position in piping tees where thermometers are indicated.
C. Install direct-mounting pressure gages in piping tees with pressure gage located on pipe at most readable position.

D. Install needle-valve and snubber fitting in piping for each pressure gage.

E. Install thermometers and gages adjacent to machines and equipment to allow service and maintenance for thermometers, gages, machines, and equipment.

F. Adjust faces of thermometers and gages to proper angle for best visibility.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes the following general-duty valves:
   1. Copper-alloy ball valves.
   2. Ferrous-alloy butterfly valves.
   5. Spring-loaded, lift-disc check valves.
   7. Cast-iron gate valves.
   8. Bronze globe valves.
   9. Cast-iron globe 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. Division 21, Fire Suppression; fire pumps and fire-protection valves.
   2. Division 22, Plumbing; specialty valves.
   3. Section 22 05 00, Common Work Results for Plumbing

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. ASME B1.20.1 Pipe Threads, General Purpose (Inch)
      b. ASME B16.1 Gray Iron Pipe Flanges and Flanged Fittings
      c. ASME B16.5 Pipe Flanges and Flanged Fittings NPS ½ through NPS 24 Metric/Inch
      d. ASME B16.10 Face to Face and End to End Dimensions of Valves
      e. ASME B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500 and 2500
f. ASME B16.34 Valves Flanged, Threaded and Welding End

2. American Water Works Association (AWWA)
   a. AWWA C606 Standard for Grooved and Shouldered Joints

3. National Sanitation Foundation (NSF)
   a. NSF 61 Drinking Water System Components

4. Manufacturers Standardization Society for the Valve and Fittings Industry (MMS)
   a. MSS SP-45 Bypass and Drain Connections
   b. MSS SP-67 Butterfly Valves
   c. MSS SP-70 Gray Iron Gate Valves, Flanged and Threaded Ends
   d. MSS SP-71 Gray Iron Swing Valves, Flanged and Threaded Ends
   e. MSS SP-80 Bronze Gate, Globe, Angle and Check Valves
   f. MSS SP-110 Ball Valves, Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Product Data: For each type of valve indicated. Include body, seating, and trim materials; valve design; pressure and temperature classifications; end connections; arrangement; dimensions; and required clearances. Include list indicating valve and its application. Include rated capacities; furnished specialties; and accessories.

1.04 QUALITY ASSURANCE
   A. ASME Compliance for Ferrous Valves: ASME B16.10 and ASME B16.34 for dimension and design criteria.
   B. NSF Compliance: NSF 61 for valve materials for potable-water service.

PART 2 - PRODUCTS

2.01 MANUFACTURERS
   A. In other Part 2, Products, Articles where subparagraph titles below introduce lists, the following requirements apply for product selection:

      1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the manufacturers specified.

2.02 VALVES, GENERAL
   A. Refer to Part 3 "Valve Applications" Article for applications of valves.
   B. Bronze Valves: NPS 2 and Smaller: Threaded ends, unless otherwise indicated.
C. Ferrous Valves: NPS 2-1/2 and Larger: Flanged ends, unless otherwise indicated.

D. Valve Pressure and Temperature Ratings: Not less than indicated and as required for system pressures and temperatures.

E. Valve Sizes: Same as upstream pipe, unless otherwise indicated.

F. Valve Actuators:
   1. Handwheel: For valves other than quarter-turn types.
   2. Lever Handle: For quarter-turn valves NPS 6 and smaller, except plug valves.

G. Extended Valve Stems: On insulated valves.


I. Valve Grooved Ends: AWWA C606.
   1. Threaded: With threads according to ASME B1.20.1.

J. Valve Bypass and Drain Connections: MSS SP-45.

2.03 COPPER-ALLOY BALL VALVES

A. Available Manufacturers:
   1. Two-Piece, Copper-Alloy Ball Valves:
      b. Crane Co.; Crane Valve Group; Stockham Div.
      c. Milwaukee Valve Company.
   2. Three-Piece, Copper-Alloy Ball Valves:
      b. Crane Co.; Crane Valve Group; Stockham Div.
      c. Milwaukee Valve Company.

B. Copper-Alloy Ball Valves, General: MSS SP-110.

C. Two-Piece, Copper-Alloy Ball Valves: Brass or bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.

D. Three-Piece, Copper-Alloy Ball Valves: Brass or bronze body with full-port, chrome-plated bronze ball; PTFE or TFE seats; and 600-psig minimum CWP rating and blowout-proof stem.
2.04 FERROUS-ALLOY BUTTERFLY VALVES

A. Available Manufacturers:

1. Flangeless, Ferrous-Alloy Butterfly Valves:
   a. American Valve, Inc.
   b. Crane Co.; Crane Valve Group; Stockham Div.
   c. Grinnell Corporation.
   d. Milwaukee Valve Company.
   e. Mueller Steam Specialty.
   f. NIBCO INC.
   g. Tyco International, Ltd.; Tyco Valves & Controls.
   h. Watts Industries, Inc.; Water Products Div.

2. Single-Flange, Ferrous-Alloy Butterfly Valves:
   a. American Valve, Inc.
   b. Crane Co.; Crane Valve Group; Stockham Div.
   c. Grinnell Corporation.
   d. Milwaukee Valve Company.
   e. Mueller Steam Specialty.
   f. NIBCO INC.
   g. Tyco International, Ltd.; Tyco Valves & Controls.
   h. Watts Industries, Inc.; Water Products Div.

B. Ferrous-Alloy Butterfly Valves, General: MSS SP-67, Type I, for tight shutoff, with disc and lining suitable for potable water, unless otherwise indicated.

C. Flangeless, 250-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Wafer type with one- or two-piece stem.

D. Flangeless, 300-psig CWP Rating, Ferrous-Alloy Butterfly Valves: Wafer type with one- or two-piece stem.


2.05 BRONZE CHECK VALVES

A. Available Manufacturers:
1. Type 2, Bronze, Horizontal Lift Check Valves with Nonmetallic Disc:
   a. Cincinnati Valve Co.
   b. Crane Co.; Crane Valve Group; Stockham Div.
   c. Walworth Co.

2. Type 1, Bronze, Vertical Lift Check Valves with Metal Disc:
   a. Cincinnati Valve Co.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Red-White Valve Corp.

3. Type 2, Bronze, Vertical Lift Check Valves with Nonmetallic Disc:
   a. Grinnell Corporation.
   b. Kitz Corporation of America.
   c. Milwaukee Valve Company.

4. Type 3, Bronze, Swing Check Valves with Metal Disc:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.
   e. Watts Industries, Inc.; Water Products Div.

5. Type 4, Bronze, Swing Check Valves with Nonmetallic Disc:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.
   e. Watts Industries, Inc.; Water Products Div.

B. Bronze Check Valves, General: MSS SP-80.

C. Type 2, Class 150, Bronze, Horizontal Lift Check Valves: Bronze body with nonmetallic disc and bronze seat.

D. Type 3, Class 200, Bronze, Swing Check Valves: Bronze body with bronze disc and seat.

E. Type 4, Class 200, Bronze, Swing Check Valves: Bronze body with nonmetallic disc and bronze seat.
2.06 GRAY-IRON SWING CHECK VALVES

A. Available Manufacturers:

1. Type I, Gray-Iron Swing Check Valves with Metal Seats:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.
   e. Watts Industries, Inc.; Water Products Div.

2. Type II, Gray-Iron Swing Check Valves with Composition to Metal Seats:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Stockham Div.

3. Grooved-End, Ductile-Iron Swing Check Valves:
   a. Grinnell Corporation.
   b. Mueller Co.
   c. Victaulic Co. of America.


C. Type I, Class 250, gray-iron, swing check valves with metal seats.

D. Type II, Class 250, gray-iron, swing check valves with composition to metal seats.

E. 175-psig CWP Rating, Grooved-End, Swing Check Valves: Ductile-iron body with grooved or shouldered ends.

F. 300-psig CWP Rating, Grooved-End, Swing Check Valves: Ductile-iron body with grooved or shouldered ends.

2.07 SPRING-LOADED, LIFT-DISC CHECK VALVES

A. Available Manufacturers:

1. Type I, Wafer Lift-Disc Check Valves:
   a. Mueller Steam Specialty.

2. Type II, Compact-Wafer, Lift-Disc Check Valves:
   a. GA Industries, Inc.
   b. Grinnell Corporation.
   c. Milwaukee Valve Company.
d. NIBCO INC.

e. Valve and Primer Corp.

3. Type III, Globe Lift-Disc Check Valves:
   a. Durabla Fluid Technology, Inc.
   b. Flomatic Valves.
   c. Grinnell Corporation.
   d. Metraflex Co.
   e. Milwaukee Valve Company.

4. Type IV, Threaded Lift-Disc Check Valves:
   a. Grinnell Corporation.
   b. Metraflex Co.
   c. Milwaukee Valve Company.

B. Lift-Disc Check Valves, General: FCI 74-1, with spring-loaded bronze or alloy disc and bronze or alloy seat.

C. Type I, Class 250, Wafer Lift-Disc Check Valves: Wafer style with cast-iron shell with diameter matching companion flanges.

D. Type II, Class 250, Compact-Wafer, Lift-Disc Check Valves: Compact-wafer style with cast-iron shell with diameter made to fit within bolt circle.

E. Type III, Class 250, Globe Lift-Disc Check Valves: Globe style with cast-iron shell and flanged ends.

F. Type IV, Class 150, Threaded Lift-Disc Check Valves: Threaded style with bronze shell and threaded ends.

2.08 BRONZE GATE VALVES

A. Available Manufacturers:

1. Type 1, Bronze, Nonrising-Stem Gate Valves:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.
   e. Watts Industries, Inc.; Water Products Div.

2. Type 2, Bronze, Rising-Stem, Solid-Wedge Gate Valves:
a. Crane Co.; Crane Valve Group; Crane Valves.
b. Crane Co.; Crane Valve Group; Jenkins Valves.
c. Crane Co.; Crane Valve Group; Stockham Div.
d. Milwaukee Valve Company.

B. Bronze Gate Valves, General: MSS SP-80, with ferrous-alloy handwheel.

C. Type 1, Class 200, Bronze Gate Valves: Bronze body with nonrising stem and bronze solid wedge and union-ring bonnet.

D. Type 2, Class 200, Bronze Gate Valves: Bronze body with rising stem and bronze solid wedge and union-ring bonnet.

2.09 CAST-IRON GATE VALVES

A. Available Manufacturers:

1. Type I, Cast-Iron, Nonrising-Stem Gate Valves:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.
   e. NIBCO INC.

2. Type I, Cast-Iron, Rising-Stem Gate Valves:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.
   e. Watts Industries, Inc.; Water Products Div.

B. Cast-Iron Gate Valves, General: MSS SP-70, Type I.

C. Class 250, NRS, Bronze-Mounted, Cast-Iron Gate Valves: Cast-iron body with bronze trim, nonrising stem, and solid-wedge disc.

D. Class 250, OS&Y, Bronze-Mounted, Cast-Iron Gate Valves: Cast-iron body with bronze trim, rising stem, and solid-wedge disc.

E. Class 250, NRS, All-Iron, Cast-Iron Gate Valves: Cast-iron body with cast-iron trim, nonrising stem, and solid-wedge disc.

F. Class 250, OS&Y, All-Iron, Cast-Iron Gate Valves: Cast-iron body with cast-iron trim, rising stem, and solid-wedge disc.
2.10 BRONZE GLOBE VALVES

A. Available Manufacturers:

1. Type 1, Bronze Globe Valves with Metal Disc:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.

2. Type 2, Bronze Globe Valves with Nonmetallic Disc:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.

B. Bronze Globe Valves, General: MSS SP-80, with ferrous-alloy handwheel.

C. Type 2, Class 200, Bronze Globe Valves: Bronze body with PTFE or TFE disc and union-ring bonnet.

2.11 CAST-IRON GLOBE VALVES

A. Available Manufacturers:

1. Type I, Cast-Iron Globe Valves with Metal Seats:
   a. Crane Co.; Crane Valve Group; Crane Valves.
   b. Crane Co.; Crane Valve Group; Jenkins Valves.
   c. Crane Co.; Crane Valve Group; Stockham Div.
   d. Milwaukee Valve Company.

B. Type I, Class 250, Cast-Iron Globe Valves: Gray-iron body with bronze seats.

PART 3 - EXECUTION

3.01 VALVE APPLICATIONS

A. Refer to piping Sections for specific valve applications. If valve applications are not indicated, use the following:

1. Shutoff Service: Ball, butterfly, gate, or plug valves.
2. Throttling Service: Angle, ball, butterfly, or globe valves.
B. If valves with specified CWP ratings are not available, the same types of valves with higher CWP ratings may be substituted.

C. Domestic Water Piping: Use the following types of valves:

1. Ball Valves, NPS 2 and Smaller: Two-piece, 600-psig CWP rating, copper alloy.
2. Ball Valves, NPS 2-1/2 and Larger: Class 300, ferrous alloy.
4. Swing Check Valves, NPS 2 and Smaller: Type 4, Class 200, bronze.
5. Swing Check Valves, NPS 2-1/2 and Larger: Type II, Class 250, gray iron.
6. Wafer Check Valves, NPS 2-1/2 and Larger: Dual-plate, wafer double-flanged, Class 250 or 300, ferrous alloy.
7. Spring-Loaded, Lift-Disc Check Valves, NPS 2 and Smaller: Type IV, Class 200.
8. Spring-Loaded, Lift-Disc Check Valves, NPS 2-1/2 and Larger: Type I or II, Class 250, cast iron.

D. Sanitary Waste and Storm Drainage Piping: Use the following types of valves:

1. Ball Valves, NPS 2 and Smaller: Two-piece, 400-psig CWP rating, copper alloy.
2. Ball Valves, NPS 2-1/2 and Larger: Class 150, ferrous alloy.
3. Swing Check Valves, NPS 2 and Smaller: Type 3, Class , bronze.
4. Swing Check Valves, NPS 2-1/2 and Larger: Type I or II, Class 125, gray iron.
5. Gate Valves, NPS 2 and Smaller: Type 1, Class 150, bronze.
6. Gate Valves, NPS 2-1/2 and Larger: Type I, Class 125, OS&Y, bronze-mounted cast iron.
7. Globe Valves, NPS 2 and Smaller: Type 1, Class 150, bronze.
8. Globe Valves, NPS 2-1/2 and Larger: Type I, Class 125, cast iron.

E. Select valves, except wafer and flangeless types, with the following end connections:

1. For Copper Tubing, NPS 2 and Smaller: threaded ends.
2. For Copper Tubing, NPS 2-1/2 to NPS 4 : Flanged ends.
3. For Copper Tubing, NPS 5 and Larger: Flanged ends.
4. For Steel Piping, NPS 2 and Smaller: Threaded ends.
5. For Steel Piping, NPS 2-1/2 to NPS 4: Flanged ends.
6. For Steel Piping, NPS 5 and Larger: Flanged ends.
3.02 VALVE INSTALLATION
   A. Piping installation requirements are specified in other Division 22 Sections. Contract Drawings indicate general arrangement of piping, fittings, and specialties.
   B. Install valves with unions or flanges at each piece of equipment arranged to allow service, maintenance, and equipment removal without system shutdown.
   C. Locate valves for easy access and provide separate support where necessary.
   D. Install valves in horizontal piping with stem at or above center of pipe.
   E. Install valves in position to allow full stem movement.
   F. Install check valves for proper direction of flow and as follows:
      1. Swing Check Valves: In horizontal position with hinge pin level.
      2. Dual-Plate Check Valves: In horizontal or vertical position, between flanges.
      3. Lift Check Valves: With stem upright and plumb.

3.03 JOINT CONSTRUCTION
   A. Refer to Section 22 05 00, Common Work Results for Plumbing, for basic piping joint construction.
   B. Grooved Joints: Assemble joints with keyed coupling housing, gasket, lubricant, and bolts according to coupling and fitting manufacturer's written instructions.

3.04 ADJUSTING
   A. Adjust or replace valve packing after piping systems have been tested and put into service but before final adjusting and balancing. Replace valves if persistent leaking occurs.

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SECTION 22 05 29

HANGERS AND SUPPORTS FOR PLUMBING PIPING AND EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following items:

1. Steel pipe hangers and supports.
2. Trapeze pipe hangers.
3. Metal framing systems.
4. Thermal-hanger shield inserts.
5. Fastener systems.
6. Equipment supports.

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 05 50 00, Metal Fabrications; structural-steel shapes and plates for trapeze hangers for pipe and equipment supports.
2. Section 21 10 00, Water-Based Fire-Suppression Systems; pipe hangers for fire-suppression piping.
3. Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment; pipe guides and anchors.
4. Section 22 05 48, Vibration and Seismic Controls for Plumbing Piping and Equipment; vibration isolation devices.

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 International (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
   c. ASTM A106 Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
   d. ASTM A123 Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
   e. ASTM A183 Standard Specification for Carbon Steel Track Bolts and Nuts
   f. ASTM A307 Standard Specification for Carbon Steel Bolts and Studs, 60000 PSI Tensile Strength
   g. ASTM A536 Standard Specification for Ductile Iron Castings
   h. ASTM A563 Standard Specification for Carbons and Alloy Steel Nuts
   i. ASTM A780 Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
   j. ASTM B16 Standard Specification for Free-Cutting Brass Rod, Bar and Shapes for Use in Screw Machines
   k. ASTM B633 Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel

4. 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

5. 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 DEFINITIONS
A. Terminology: As defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."

1.04 PERFORMANCE REQUIREMENTS
A. Design supports for multiple pipes capable of supporting combined weight of supported systems, system contents, and test water.
B. Design equipment supports capable of supporting combined operating weight of supported equipment and connected systems and components.
C. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from authorities having jurisdiction.

1.05 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For the following:
   1. Steel pipe hangers and supports.
   2. Thermal-hanger shield inserts.
   3. Powder-actuated fastener systems.
C. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following:
   1. Trapeze pipe hangers. Include Product Data for components.
   2. Metal framing systems. Include Product Data for components.
   3. Equipment supports.
D. Welding certificates. In accordance with welding specification.

1.06 QUALITY ASSURANCE
A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.01 MANUFACTURERS
A. In other Part 2 Articles where titles below introduce lists, the following requirements apply to product selection:
   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.
2.02 STEEL PIPE HANGERS AND SUPPORTS

A. Description: MSS SP-58, Types 1 through 58, factory-fabricated components. Refer to Article 3.01 for locations to use specific hanger and support types.

B. Available Manufacturers:

1. AAA Technology & Specialties Co., Inc.
2. Bergen-Power Pipe Supports.
4. Carpenter & Paterson, Inc.
5. Empire Industries, Inc.
6. ERICO/Michigan Hanger Co.
7. Globe Pipe Hanger Products, Inc.
8. Grinnell Corp.
9. GS Metals Corp.
11. PHD Manufacturing, Inc.
12. PHS Industries, Inc.
13. Piping Technology & Products, Inc.
14. Tolco Inc.

C. Galvanized, Metallic Coatings: Pregalvanized or hot dipped.

D. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion for support of bearing surface of piping.

2.03 TRAPEZE PIPE HANGERS

A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural-steel shapes with MSS SP-58 hanger rods, nuts, saddles, and U-bolts.

2.04 METAL FRAMING SYSTEMS

A. Description: MFMA-3, shop- or field-fabricated pipe-support assembly made of steel channels and other components.

B. Available Manufacturers:

2. ERICO/Michigan Hanger Co.; ERISTRUT Div.
3. GS Metals Corp.
5. Thomas & Betts Corporation.
6. Tolco Inc.
7. Unistrut Corp.; Tyco International, Ltd.

C. Coatings: Manufacturer’s standard finish, unless bare metal surfaces are indicated.
D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

2.05 THERMAL-HANGER SHIELD INSERTS

A. Description: 100-psig minimum, compressive-strength insulation insert encased in sheet metal shield.
B. Available Manufacturers:
   1. Carpenter & Paterson, Inc.
   2. ERICO/Michigan Hanger Co.
   3. PHS Industries, Inc.
   4. Pipe Shields, Inc.
   5. Rilco Manufacturing Company, Inc.
   6. Value Engineered Products, Inc.
C. Insulation-Insert Material for Cold Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass with vapor barrier.
D. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass.
E. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
F. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
G. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.06 FASTENER SYSTEMS

A. Mechanical-Expansion Anchors: Insert-wedge-type stainless steel, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.
   1. Available Manufacturers:
      b. Empire Industries, Inc.
      c. Hilti, Inc.
      d. ITW Ramset/Red Head.
2.07 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural-steel shapes.

2.08 MISCELLANEOUS MATERIALS

A. Structural Steel: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.
2. Design Mix: 5000-psi, 28-day compressive strength.

PART 3 - EXECUTION

3.01 HANGER AND SUPPORT APPLICATIONS

A. Specific hanger and support requirements are specified in Sections specifying piping systems and equipment.

B. Comply with MSS SP-69 for pipe hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized, metallic coatings for piping and equipment that will not have field-applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use padded hangers for piping that is subject to scratching.

F. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated stationary pipes, NPS 1/2 to NPS 30.

2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of 120 to 450 deg F pipes, NPS 4 to NPS 16, requiring up to 4 inches of insulation.

3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes, NPS 3/4 to NPS 24, requiring clamp flexibility and up to 4 inches of insulation.

4. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.

5. U-Bolts (MSS Type 24): For support of heavy pipes, NPS 1/2 to NPS 30.
6. **Pipe Saddle Supports (MSS Type 36):** For support of pipes, NPS 4 to NPS 36, with steel pipe base stanchion support and cast-iron floor flange.

7. **Single Pipe Rolls (MSS Type 41):** For suspension of pipes, NPS 1 to NPS 30, from 2 rods if longitudinal movement caused by expansion and contraction might occur.

8. **Complete Pipe Rolls (MSS Type 44):** For support of pipes, NPS 2 to NPS 42, if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.

G. **Vertical-Piping Clamps:** Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. **Extension Pipe or Riser Clamps (MSS Type 8):** For support of pipe risers, NPS 3/4 to NPS 20.

2. **Carbon- or Alloy-Steel Riser Clamps (MSS Type 42):** For support of pipe risers, NPS 3/4 to NPS 20, if longer ends are required for riser clamps.

H. **Hanger-Rod Attachments:** Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. **Steel Turnbuckles (MSS Type 13):** For adjustment up to 6 inches for heavy loads.

2. **Steel Clevises (MSS Type 14):** For 120 to 450 deg F piping installations.

I. **Building Attachments:** Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. **Steel or Malleable Concrete Inserts (MSS Type 18):** For upper attachment to suspend pipe hangers from concrete ceiling.

2. **Top-Beam C-Clamps (MSS Type 19):** For use under roof installations with bar joist construction to attach to top flange of structural shape.

3. **Side-Beam or Channel Clamps (MSS Type 20):** For attaching to bottom flange of beams, channels, or angles.

4. **Center-Beam Clamps (MSS Type 21):** For attaching to center of bottom flange of beams.

5. **Welded Beam Attachments (MSS Type 22):** For attaching to bottom of beams if loads are considerable and rod sizes are large.

6. **C-Clamps (MSS Type 23):** For structural shapes.

7. **Welded-Steel Brackets:** For support of pipes from below, or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. **Light (MSS Type 31):** 750 lb.
   b. **Medium (MSS Type 32):** 1500 lb.
   c. **Heavy (MSS Type 33):** 3000 lb.

8. **Side-Beam Brackets (MSS Type 34):** For sides of steel or wooden beams.
9. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.

J. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.

2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.

3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

K. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches

2. Spring-Cushion Roll Hangers (MSS Type 49): For equipping Type 41 roll hanger with springs.

3. Variable-Spring Base Supports (MSS Type 52): Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from base support.

L. Comply with MSS SP-69 for trapeze pipe hanger selections and applications that are not specified in piping system Sections.

M. Comply with MFMA-102 for metal framing system selections and applications that are not specified in piping system Sections.

N. Use mechanical-expansion anchors instead of building attachments where required in concrete construction.

3.02 HANGER AND SUPPORT INSTALLATION

A. Steel Pipe Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure.

B. Trapeze Pipe Hanger Installation: Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping and support together on field-fabricated trapeze pipe hangers.

1. Pipes of Various Sizes: Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified above for individual pipe hangers.

2. Field fabricate from ASTM A 36/A 36M, steel shapes selected for loads being supported. Weld steel according to AWS D1.1.

C. Metal Framing System Installation: Arrange for grouping of parallel runs of piping and support together on field-assembled metal framing systems.

D. Thermal-Hanger Shield Installation: Install in pipe hanger or shield for insulated piping.
E. Fastener System Installation:

1. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

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


H. 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 expansion joints, expansion loops, expansion bends, and similar units.

I. Install lateral bracing with pipe hangers and supports to prevent swaying.

J. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

K. Load Distribution: Install hangers and supports so piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

L. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.9 (for building services piping) are not exceeded.

M. Insulated Piping: Comply with the following:

1. Attach clamps and spacers to piping.
   
   a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
   
   b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
   
   c. Do not exceed pipe stress limits according to ASME B31.9 for building services piping.

2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.

3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.

4. Shield Dimensions for Pipe: Not less than the following:

   a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
   
   b. NPS 4: 12 inches long and 0.06 inch thick.
   
   c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
   
   d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.

5. Pipes NPS 8 and Larger: Include wood inserts.

6. Insert Material: Length at least as long as protective shield.

7. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.03 EQUIPMENT SUPPORTS

A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

B. Grouting: Place grout under supports for equipment and make smooth bearing surface.

C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.04 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

C. Field Welding: Comply with AWS D1.1 procedures for shielded metal arc welding, appearance and quality of welds, and methods used in correcting welding work, and with 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. Finish welds at exposed connections so no roughness shows after finishing and contours of welded surfaces match adjacent contours.

3.05 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

3.06 PAINTING

A. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following:
   1. Isolation pads.
   2. Isolation mounts.
   3. Restrained elastomeric isolation mounts.
   4. Freestanding and restrained spring isolators.
   5. Housed spring mounts.
   6. Elastomeric hangers.
   7. Spring hangers.
   8. Spring hangers with vertical-limit stops.
   9. Pipe riser resilient supports.
  10. Resilient pipe guides.
  11. Restraining braces and cables.

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 22 11 16, Domestic Water Piping.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society for Testing and Materials International (ASTM)
      a. ASTM A53 Standard Specification for Stainless Steel Rope Wire
   2. American Welding Society (AWS)
      a. AWS D1.1/D1.1M Structural Welding Code – Steel, Second Printing, Errata
   3. City of Seattle (COS):
      a. Seattle Fire Code (International Fire Code with Seattle Amendments)
4. Manufacturers Standardization Society for the Valve and Fittings Industry
   a. MSS SP-127 Bracing for Piping Systems Seismic-Wind-Dynamic Design, Selection, Application

1.03 PERFORMANCE REQUIREMENTS

A. Seismic-Restraint Loading:
   1. Site Class as Defined in the IBC: C.
   2. Assigned Seismic Use Group or Building Category as Defined in the IBC: II.
      a. Component Importance Factor: 1.5.
      b. Component Response Modification Factor: 2.5.
      c. Component Amplification Factor: 2.5.
   3. Design Spectral Response Acceleration at Short Periods (0.2 Second): 10.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each product indicated.
C. Delegated-Design Submittal: For vibration isolation and seismic-restraint calculations and details indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
D. Welding certificates.
E. Qualification Data: For professional engineer.
F. Field quality-control test reports.

1.05 QUALITY ASSURANCE

A. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.
B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."
C. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage pre approved by ICC-ES, or pre-approved by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If pre-approved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.
PART 2 - PRODUCTS

2.01 VIBRATION ISOLATORS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

B. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Contract Drawings or a comparable product by one of the following:

1. Ace Mountings Co., Inc.
2. Amber/Booth Company, Inc.
4. Isolation Technology, Inc.
7. Vibration Eliminator Co., Inc.
8. Vibration Isolation.

C. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.

1. Resilient Material: Oil- and water-resistant rubber.

D. Mounts: Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.

1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.

E. Restrained Mounts: All-directional mountings with seismic restraint.

1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.
F. Spring Isolators: Freestanding, laterally stable, open-spring isolators.

1. **Outside Spring Diameter:** Not less than 80 percent of the compressed height of the spring at rated load.

2. **Minimum Additional Travel:** 50 percent of the required deflection at rated load.

3. **Lateral Stiffness:** More than 80 percent of rated vertical stiffness.

4. **Overload Capacity:** Support 200 percent of rated load, fully compressed, without deformation or failure.

5. **Baseplates:** Factory drilled for bolting to structure and bonded to 1/4-inch-thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to 500 psig.

6. **Top Plate and Adjustment Bolt:** Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

G. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic or limit-stop restraint.

1. **Housing:** Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch-thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.

2. **Restraint:** Seismic or limit-stop as required for equipment and authorities having jurisdiction.

3. **Outside Spring Diameter:** Not less than 80 percent of the compressed height of the spring at rated load.

4. **Minimum Additional Travel:** 50 percent of the required deflection at rated load.

5. **Lateral Stiffness:** More than 80 percent of rated vertical stiffness.

6. **Overload Capacity:** Support 200 percent of rated load, fully compressed, without deformation or failure.

H. Housed Spring Mounts: Housed spring isolator with integral seismic snubbers.

1. **Housing:** Ductile-iron or steel housing to provide all-directional seismic restraint.

2. **Base:** Factory drilled for bolting to structure.

3. **Snubbers:** Vertically adjustable to allow a maximum of 1/4-inch travel up or down before contacting a resilient collar.

I. Elastomeric Hangers: Single or double-deflection type, fitted with molded, oil-resistant elastomeric isolator elements bonded to steel housings with threaded connections for hanger rods. Color-code or otherwise identify to indicate capacity range.

J. Spring Hangers: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression.
1. **Frame**: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.

2. **Outside Spring Diameter**: Not less than 80 percent of the compressed height of the spring at rated load.

3. **Minimum Additional Travel**: 50 percent of the required deflection at rated load.

4. **Lateral Stiffness**: More than 80 percent of rated vertical stiffness.

5. **Overload Capacity**: Support 200 percent of rated load, fully compressed, without deformation or failure.

6. **Elastomeric Element**: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.

7. **Self-centering hanger rod cap**: to ensure concentricity between hanger rod and support spring coil.

K. **Spring Hangers with Vertical-Limit Stop**: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression and with a vertical-limit stop.

1. **Frame**: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.

2. **Outside Spring Diameter**: Not less than 80 percent of the compressed height of the spring at rated load.

3. **Minimum Additional Travel**: 50 percent of the required deflection at rated load.

4. **Lateral Stiffness**: More than 80 percent of rated vertical stiffness.

5. **Overload Capacity**: Support 200 percent of rated load, fully compressed, without deformation or failure.

6. **Elastomeric Element**: Molded, oil-resistant rubber or neoprene.

7. **Adjustable Vertical Stop**: Steel washer with neoprene washer “up-stop” on lower threaded rod.

8. **Self-centering hanger rod cap**: to ensure concentricity between hanger rod and support spring coil.

L. **Pipe Riser Resilient Support**: All-directional, acoustical pipe anchor consisting of 2 steel tubes separated by a minimum of 1/2-inch thick neoprene. Include steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions. Design support for a maximum load on the isolation material of 500 psig and for equal resistance in all directions.

M. **Resilient Pipe Guides**: Telescopic arrangement of 2 steel tubes or post and sleeve arrangement separated by a minimum of 1/2-inch thick neoprene. Where clearances are not readily visible, a factory-set guide height with a shear pin to allow vertical motion due to pipe expansion and contraction shall be fitted. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.
2.02 SEISMIC-RESTRAINT DEVICES

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work.

B. Basis-of-Design Product: Subject to compliance with requirements, provide the product required for the equipment indicated on Contract Drawings or a comparable product by one of the following:

1. Amber/Booth Company, Inc.
2. California Dynamics Corporation.
3. Cooper B-Line, Inc.; a division of Cooper Industries.
4. Hilti, Inc.
7. Mason Industries.
8. TOLCO Incorporated; a brand of NIBCO INC.
9. Unistrut; Tyco International, Ltd.

C. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an agency acceptable to authorities having jurisdiction.

1. 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.

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

E. Restraint Cables: ASTM A 492 stainless-steel cables with end connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; and with a minimum of two clamping bolts for cable engagement.

F. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections to hanger rod.

G. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.

H. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.

I. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488. Minimum length of eight times diameter.
PART 3 - EXECUTION

3.01 APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an agency acceptable to authorities having jurisdiction.

B. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Contract Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.

C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

3.02 VIBRATION-CONTROL AND SEISMIC-RESTRAINT DEVICE INSTALLATION

A. Equipment Restraints:
   1. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
   2. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction providing required submittals for component.

B. Piping Restraints:
   1. Comply with requirements in MSS SP-127.
   2. Space lateral supports a maximum of 40 feet on center (o.c.), and longitudinal supports a maximum of 80 feet o.c.
   3. Brace a change of direction longer than 12 feet.

C. Install cables so they do not bend across edges of adjacent equipment or building structure.

D. Install seismic-restraint devices using methods approved by an agency acceptable to authorities having jurisdiction providing required submittals for component.

E. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.

F. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.

G. Drilled-in Anchors:
   1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.
2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.

4. Set anchors to manufacturer's recommended torque, using a torque wrench.

5. Install zinc-coated steel anchors for interior and stainless steel anchors for exterior applications.

3.03 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Section 22 11 16, Domestic Water Piping for piping flexible connections.

3.04 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. Provide evidence of recent calibration of test equipment by a testing agency acceptable to Resident engineer and the City of Seattle Code Authorities.

2. Schedule test with Resident Engineer, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least 7 days' advance notice.

3. Obtain Resident Engineer's approval before transmitting test loads to structure. Provide temporary load-spreading members.

4. Test at least four of each type and size of installed anchors and fasteners selected by Resident Engineer.

5. Test to 90 percent of rated proof load of device.


7. Measure isolator deflection.

8. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.

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

D. Prepare test and inspection reports.

3.05 ADJUSTING

A. Adjust isolators after piping system is at operating weight.
B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

C. Adjust active height of spring isolators.

D. Adjust restraints to permit free movement of equipment within normal mode of operation.

3.06 PLUMBING VIBRATION-CONTROL AND SEISMIC-RESTRAINT DEVICE SCHEDULE

A. As Indicated on Contract Drawings

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. Section Includes:
   1. Equipment labels.
   2. Warning signs and labels.
   3. Pipe labels.
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 96 00, High-Performance Coatings.

1.02 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each type of product indicated.

PART 2 - PRODUCTS

2.01 EQUIPMENT LABELS
A. Metal Labels for Equipment:
   1. Material and Thickness: Stainless steel, 0.025-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.
   2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.
   3. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
   5. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.
B. Label Content: Include equipment's Contract Drawing designation or unique equipment number, Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specification Section number and title where equipment is specified.
C. Equipment Label Schedule: For each item of equipment to be labeled, on 8-1/2 by 11-inch bond paper. Tabulate equipment identification number and identify Contract Drawing numbers where equipment is indicated (plans, details, and schedules), plus the Contract Specifications Section number and title where equipment is specified. Equipment schedule shall be included in operation and maintenance data.

2.02 WARNING SIGNS AND LABELS FOR BACK OF HOUSE

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.


C. Background Color: Black.

D. Maximum Temperature: Able to withstand temperatures up to 160 degrees F.

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. Fasteners: Stainless-steel rivets or self-tapping screws.

H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

I. Label Content: Include caution and warning information, plus emergency notification instructions.

2.03 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.

B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to cover full circumference of pipe and to attach to pipe without fasteners or adhesive.

C. Self-Adhesive Pipe Labels: Printed plastic with contact-type, permanent-adhesive backing.

D. Pipe Label Contents: Include identification of piping service using same designations or abbreviations as used on Contract Drawings, pipe size, and an arrow indicating flow direction.

1. Flow-Direction Arrows: Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.

2. Lettering Size: At least 1-1/2 inches high.
PART 3 - EXECUTION

3.01 PREPARATION
   A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.02 EQUIPMENT LABEL INSTALLATION
   A. Install or permanently fasten labels on each major item of mechanical equipment.
   B. Locate equipment labels where accessible and visible.

3.03 PIPE LABEL INSTALLATION
   A. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:
      1. Near each valve and control device.
      2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
      3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
      4. At access doors, manholes, and similar access points that permit view of concealed piping.
      5. Near major equipment items and other points of origination and termination.
      6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 feet in areas of congested piping and equipment.
   B. Pipe Label Color Schedule:
      1. Domestic Water Piping:
         a. Background Color: Blue.
      2. Sanitary Waste Piping:
3. Storm Drainage Piping:
   
a. Background Color: Black.


END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for:

1. Insulation Materials:
   a. Mineral fiber.

2. Insulating cements.

3. Adhesives.


5. Sealants.

6. Factory-applied jackets.


8. Field-applied jackets.


10. Securements.

11. Corner angles.

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 07 84 00, Firestopping.

2. Section 09 90 00, Painting and Coating.

3. Section 23 07 00 HVAC Insulation.

1.02 REFERENCES

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

1. American Society for Testing and Materials International (ASTM)
   a. ASTM B209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
c. ASTM C553 Standard Specification for Mineral Fiber Blanket Insulation for Commercial and Industrial Applications

d. ASTM C612 Standard Specification for Mineral Fiber Block and Board Thermal Insulation

e. ASTM C871 Standard Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate, and Sodium Ions

f. ASTM C921 Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation

g. ASTM C1136 Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation

h. ASTM C1393 Standard Specification for Perpendicularly Oriented Mineral Fiber Roll and Sheet Insulation for Pipes and Tanks

i. ASTM D1644 Standard Test Methods for Nonvolatile Content of Varnishes

j. ASTM E84 Standard Test Methods for Surface Burning Characteristics of Building Materials

k. ASTM E96 Standard Test Methods for Water Vapor Transmission of Materials

l. ASTM F1249 Standard Test Methods for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor

2. City of Seattle (COS):

   a. Seattle Fire Code (International Fire Code with Seattle Amendments)

3. 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

4. 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 product indicated.

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 pipe expansion joints for each type of insulation.
   4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
   5. Detail removable insulation at piping specialties, equipment connections, and access panels.
   6. Detail application of field-applied jackets.
   7. Detail application at linkages of control devices.
   8. Detail field application for each equipment type.

D. Field quality-control reports.

1.04 QUALITY ASSURANCE

A. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per ASTM E 84, by an Independent Testing Laboratory acceptable to Resident Engineer and the City of Seattle Code authority. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable Independent Testing Laboratory.

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

   2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Insulation Materials

   1. Comply with requirements in Article 3.04 for where insulating materials shall be applied.

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

   3. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

   4. High-Temperature, Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type V, without factory-applied jacket.
a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Johns Manville; HTB 23 Spin-Glas.
2) Owens Corning; High Temperature Flexible Batt Insulations.

5. For operating temperatures higher than 250 degrees F, use high-temperature board insulation in first paragraph below.


a. See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. See Section 01 66 00, Product Storage and Handling Requirements.

b. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Fibrex Insulations Inc.; FBX.
2) Johns Manville; 1000 Series Spin-Glas.
3) Owens Corning; High Temperature Industrial Board Insulations.
4) Rock Wool Manufacturing Company; Delta Board.
5) Roxul Inc.; Roxul RW.
6) Thermafiber; Thermafiber Industrial Felt.

7. Mineral-Fiber, Preformed Pipe Insulation:

a. See Editing Instruction No. 1 in the Evaluations for cautions about naming manufacturers and products. See Section 01 66 00, Product Storage and Handling Requirements.

b. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Fibrex Insulations Inc.; Coreplus 1200.
2) Johns Manville; Micro-Lok.
3) Knauf Insulation; 1000 Pipe Insulation.
4) Manson Insulation Inc.; Alley-K.
5) Owens Corning; Fiberglas Pipe Insulation.

8. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied FSK jacket complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more.
Thermal conductivity (k-value) at 100 degrees F is 0.29 Btu x in./h x sq. ft. x degrees F or less. Factory-applied jacket requirements are specified in "Factory-Applied Jackets" Article.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   1) CertainTeed Corp.; CrimpWrap.
   2) Johns Manville; MicroFlex.
   3) Knauf Insulation; Pipe and Tank Insulation.
   4) Manson Insulation Inc.; AK Flex.
   5) Owens Corning; Fiberglas Pipe and Tank Insulation.

B. Insulating Cements

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Insulco, Division of MFS, Inc.; SmoothKote.
      3) Rock Wool Manufacturing Company; Delta One Shot.

C. Adhesives

1. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated, unless otherwise indicated.

2. Cellular-Glass Polystyrene Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 degrees F.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; CP-96.
      2) Foster Products Corporation, H. B. Fuller Company; 81-33.

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; CP-82.
      2) Foster Products Corporation, H. B. Fuller Company; 85-20.
3) ITW TACC, Division of Illinois Tool Works; S-90/80.
4) Marathon Industries, Inc.; 225.
5) Mon-Eco Industries, Inc.; 22-25.

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

5. Vapor-Barrier Mastic: Water based; suitable for indoor and outdoor use on below ambient services.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; CP-35.
      2) Foster Products Corporation, H. B. Fuller Company; 30-90.
      3) ITW TACC, Division of Illinois Tool Works; CB-50.
      4) Marathon Industries, Inc.; 590.
      5) Mon-Eco Industries, Inc.; 55-40.
      6) Vimasco Corporation; 749.
   b. Water-Vapor Permeance: ASTM E 96, Procedure B, 0.013 perm at 43-mil dry film thickness.
   c. Service Temperature Range: Minus 20 to plus 180 degrees F.
   d. Solids Content: ASTM D 1644, 59 percent by volume and 71 percent by weight.
   e. Color: White.

6. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; CP-10.
      2) Foster Products Corporation, H. B. Fuller Company; 35-00.
      3) ITW TACC, Division of Illinois Tool Works; CB-05/15.
      6) Vimasco Corporation; WC-1/WC-5.
   b. Water-Vapor Permeance: ASTM F 1249, 3 perms at 0.0625-inch dry film thickness.
c. Service Temperature Range: Minus 20 to plus 200 degrees F.
d. Solids Content: 63 percent by volume and 73 percent by weight.
e. Color: White.

D. Sealants

1. Joint Sealants:
   a. Joint Sealants for Cellular-Glass Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; CP-76.
      2) Foster Products Corporation, H. B. Fuller Company; 30-45.
      3) Marathon Industries, Inc.; 405.
      4) Mon-Eco Industries, Inc.; 44-05.
      5) Pittsburgh Corning Corporation; Pittseal 444.
      6) Vimasco Corporation; 750.
   b. Materials shall be compatible with insulation materials, jackets, and substrates.
   c. Permanently flexible, elastomeric sealant.
   d. Service Temperature Range: Minus 100 to plus 300 degrees F.
   e. Color: White or gray.

2. FSK and Metal Jacket Flashing Sealants:
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; CP-76-8.
      2) Foster Products Corporation, H. B. Fuller Company; 95-44.
      3) Marathon Industries, Inc.; 405.
      4) Mon-Eco Industries, Inc.; 44-05.
      5) Vimasco Corporation; 750.
   b. Materials shall be compatible with insulation materials, jackets, and substrates.
   c. Fire- and water-resistant, flexible, elastomeric sealant.
   d. Service Temperature Range: Minus 40 to plus 250 degrees F.
   e. Color: Aluminum.
E. Factory-Applied Jackets

1. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:
   a. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

F. Field-Applied Jackets

1. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Childers Products, Division of ITW; Metal Jacketing Systems.
      2) PABCO Metals Corporation; Surefit.
      3) RPR Products, Inc.; Insul-Mate.
   b. Sheet and roll stock ready for shop or field sizing.
   c. Finish and thickness are indicated in field-applied jacket schedules.
   d. Moisture Barrier for Indoor Applications: 2.5-mil-thick Polysurlyn.
   e. Moisture Barrier for Outdoor Applications: 2.5-mil-thick Polysurlyn.
   f. Factory-Fabricated Fitting Covers:
      1) Same material, finish, and thickness as jacket.
      2) Preformed 2-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.

a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

1) Pittsburgh Corning Corporation; Pittwrap.
2) Polyguard; Insulrap No Torch 125.

G. Tapes

1. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Avery Dennison Corporation, Specialty Tapes Division; Fasson 0827.
      2) Compac Corp.; 110 and 111.
      3) Ideal Tape Co., Inc., an American Biltrite Company; 491 AWF FSK.
      4) Venture Tape; 1525 CW, 1528 CW, and 1528 CW/SQ.
   b. Width: 3 inches.
   c. Thickness: 6.5 mils.
   d. Adhesion: 90 ounces force/inch in width.
   e. Elongation: 2 percent.
   f. Tensile Strength: 40 lbf/inch in width.
   g. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) Avery Dennison Corporation, Specialty Tapes Division; Fasson 0800.
      2) Compac Corp.; 120.
      3) Ideal Tape Co., Inc., an American Biltrite Company; 488 AWF FSK.
      4) Venture Tape; 3520 CW.
   b. Width: 2 inches.
   c. Thickness: 3.7 mils.
   d. Adhesion: 100 ounces force/inch in width.
e. Elongation: 5 percent.

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

H. Securements

1. Aluminum Bands: ASTM B 209 (ASTM B 209M), Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing or closed seal.

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

      1) Childers Products; Bands.
      2) PABCO Metals Corporation; Bands.
      3) RPR Products, Inc.; Bands.

2. Insulation Pins and Hangers:

   a. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

      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) AGM Industries, Inc.; Tactoo Insul-Hangers, Series T.
         b) GEMCO; Perforated Base.
         c) Midwest Fasteners, Inc.; Spindle.

            i) Baseplate: Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.
            ii) Spindle: Stainless steel, fully annealed, 0.106-inch diameter shank, length to suit depth of insulation indicated.
            iii) Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

   b. Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

      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) GEMCO; Nylon Hangers.

b) Midwest Fasteners, Inc.; Nylon Insulation Hangers.

i) Baseplate: Perforated, nylon sheet, 0.030 inch thick by 1-1/2 inches in diameter.

ii) Spindle: Nylon, 0.106-inch-diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches.

iii) Adhesive: Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

c. Self-Sticking-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

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) AGM Industries, Inc.; Tactoo Insul-Hangers, Series TSA.

   b) GEMCO; Press and Peel.

   c) Midwest Fasteners, Inc.; Self Stick.

2) Baseplate: Galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.

3) Spindle: Stainless steel, fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.

4) Adhesive-backed base with a peel-off protective cover.

d. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick, stainless-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

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) AGM Industries, Inc.; RC-150.

   b) GEMCO; R-150.

   c) Midwest Fasteners, Inc.; WA-150.

   d) Nelson Stud Welding; Speed Clips.
2) Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

e. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

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) GEMCO.

   b) Midwest Fasteners, Inc.


I. Corner Angles

1. Aluminum Corner Angles: 0.040 inch thick, minimum 1 by 1 inch, aluminum according to ASTM B 209, Alloy 3003, 3005, 3105 or 5005; Temper H-14.

PART 3 - EXECUTION

3.01 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.

3.02 INSTALLATION

A. General Installation Requirements

1. 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.

2. Install insulation materials, forms, vapor barriers or retarders, jackets, and thicknesses required for each item of equipment and pipe system as specified in insulation system schedules.

3. 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.

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

5. Install multiple layers of insulation with longitudinal and end seams staggered.
6. Do not weld brackets, clips, or other attachment devices to piping, fittings, and specialties.


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

9. Install insulation with least number of joints practical.

10. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.
   
   a. Install insulation continuously through hangers and around anchor attachments.
   
   b. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.
   
   c. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
   
   d. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

11. Apply adhesives, mastics, and sealants at manufacturer's recommended coverage rate and wet and dry film thicknesses.

12. Install insulation with factory-applied jackets as follows:
   
   a. Draw jacket tight and smooth.
   
   b. 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.
   
   c. 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.
      
      1) For below ambient services, apply vapor-barrier mastic over staples.
   
   d. Cover joints and seams with tape as recommended by insulation material manufacturer to maintain vapor seal.
   
   e. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints at ends adjacent to pipe flanges and fittings.

13. Cut insulation in a manner to avoid compressing insulation more than 75 percent of its nominal thickness.
14. Finish installation with systems at operating conditions. Repair joint separations and cracking due to thermal movement.

15. 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.

16. For above ambient services, do not install insulation to the following:
   a. Vibration-control devices.
   b. Independent Testing Laboratory labels and stamps.
   c. Nameplates and data plates.
   d. Manholes.
   e. Handholes.
   f. Cleanouts.

B. Penetrations

1. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
   a. Seal penetrations with flashing sealant.
   b. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
   c. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.
   d. Seal jacket to roof flashing with flashing sealant.

2. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

3. Insulation Installation at Aboveground Exterior Wall Penetrations: Install insulation continuously through wall penetrations.
   a. Seal penetrations with flashing sealant.
   b. For applications requiring only indoor insulation, terminate insulation inside wall surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.
   c. Extend jacket of outdoor insulation outside wall flashing and overlap wall flashing at least 2 inches.
   d. Seal jacket to wall flashing with flashing sealant.

4. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.
5. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions.
   a. Comply with requirements in Section 07 84 00, Firestopping.

6. Insulation Installation at Floor Penetrations:
   a. Pipe: Install insulation continuously through floor penetrations.
   b. Seal penetrations through fire-rated assemblies. Comply with requirements in Section 07 84 00, Firestopping.

C. Equipment, Tank, and Vessel Insulation Installation

1. Mineral Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.
   a. Apply adhesives according to manufacturer's recommended coverage rates per unit area, for 100 percent coverage of tank and vessel surfaces.
   b. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.
   c. Protect exposed corners with secured corner angles.
   d. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:
      1) Do not weld anchor pins to ASME-labeled pressure vessels.
      2) Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
      3) On tanks and vessels, maximum anchor-pin spacing is 3 inches from insulation end joints, and 16 inches on center in both directions.
      4) Do not overcompress insulation during installation.
      5) Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.
      6) Impale insulation over anchor pins and attach speed washers.
      7) Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
   e. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.
   f. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment...
approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.

g. Stagger joints between insulation layers at least 3 inches.

h. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.

i. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.

j. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

2. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.

a. Apply 100 percent coverage of adhesive to surface with manufacturer’s recommended adhesive.

b. Seal longitudinal seams and end joints.

D. General Pipe Insulation Installation

1. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.

2. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:

a. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity, unless otherwise indicated.

b. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.

c. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.

d. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-boxes.
studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.

e. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below ambient services, provide a design that maintains vapor barrier.

f. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.

g. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below ambient services and a breather mastic for above ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.

h. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.

i. Stencil or label the outside insulation jacket of each union with the word "UNION." Match size and color of pipe labels.

3. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes, vessels, and equipment. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

4. Install removable insulation covers at locations indicated. Installation shall conform to the following:

a. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.

b. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.

c. Construct removable valve insulation covers in same manner as for flanges except divide the two-part section on the vertical center line of valve body.
d. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.

e. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

E. Cellular-Glass Insulation Installation

1. Insulation Installation on Straight Pipes and Tubes:
   a. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
   b. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
   c. For insulation with factory-applied jackets on above ambient services, secure laps with outward clinched staples at 6 inches o.c.
   d. For insulation with factory-applied jackets on below ambient services, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

2. Insulation Installation on Pipe Flanges:
   a. Install preformed pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.
   d. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.
   b. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.

4. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed sections of cellular-glass insulation to valve body.
b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

c. Install insulation to flanges as specified for flange insulation application.

F. Mineral-Fiber Insulation Installation

1. Insulation Installation on Straight Pipes and Tubes:
   a. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.
   b. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.
   c. For insulation with factory-applied jackets on above ambient surfaces, secure laps with outward clinched staples at 6 inches o.c.
   d. For insulation with factory-applied jackets on below ambient surfaces, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

2. Insulation Installation on Pipe Flanges:
   a. Install preformed pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.
   d. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install preformed sections of same material as straight segments of pipe insulation when available.
   b. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

4. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed sections of same material as straight segments of pipe insulation when available.
   b. When preformed sections are not available, install mitered sections of pipe insulation to valve body.
   c. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   d. Install insulation to flanges as specified for flange insulation application.
G. Polyolefin Insulation Installation

1. Insulation Installation on Straight Pipes and Tubes:
   a. Seal split-tube longitudinal seams and end joints with manufacturer’s recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

2. Insulation Installation on Pipe Flanges:
   a. Install pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polyolefin sheet insulation of same thickness as pipe insulation.
   d. Secure insulation to flanges and seal seams with manufacturer’s recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3. Insulation Installation on Pipe Fittings and Elbows:
   a. Install mitered sections of polyolefin pipe insulation.
   b. Secure insulation materials and seal seams with manufacturer’s recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

4. Insulation Installation on Valves and Pipe Specialties:
   a. Install cut sections of polyolefin pipe and sheet insulation to valve body.
   b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   c. Install insulation to flanges as specified for flange insulation application.
   d. Secure insulation to valves and specialties, and seal seams with manufacturer’s recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

5. Insulation Installation on Pipe Flanges:
   a. Install preformed pipe insulation to outer diameter of pipe flange.
   b. Make width of insulation section same as overall width of flange and bolts, same thickness of adjacent pipe insulation, not to exceed 1-1/2-inch thickness.
   c. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of polystyrene block insulation of same thickness as pipe insulation.

6. Insulation Installation on Pipe Fittings and Elbows:
a. Install preformed insulation sections of same material as straight segments of pipe insulation. Secure according to manufacturer's written instructions.

7. Insulation Installation on Valves and Pipe Specialties:
   a. Install preformed section of polystyrene insulation to valve body.
   b. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.
   c. Install insulation to flanges as specified for flange insulation application.

H. Field-Applied Jacket Installation
   1. Where FSK jackets are indicated, install as follows:
      a. Draw jacket material smooth and tight.
      b. Install lap or joint strips with same material as jacket.
      c. Secure jacket to insulation with manufacturer's recommended adhesive.
      d. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch-wide joint strips at end joints.
      e. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

   2. Where metal jackets are indicated, install with 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 on center and at end joints.

I. Underground, Field-Installed Insulation Jacket
   1. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

3.03 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:
   1. Inspect field-insulated equipment, 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 one location(s) for each type of equipment defined in the “Equipment Insulation Schedule” Article. For large equipment, remove only a portion adequate to determine compliance.

   2. 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 threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in the “Piping Insulation Schedule, General” Article.
C. All insulation applications will be considered defective work if sample inspection reveals noncompliance with requirements.

3.04 SCHEDULES

A. Equipment Insulation Schedule

1. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.

2. Insulate indoor and outdoor equipment in Articles below that is not factory insulated.

3. Domestic water, domestic chilled-water (potable), and domestic hot-water hydropneumatic tank insulation shall be the following:


B. Piping Insulation Schedule, General

1. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

2. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:
   a. Drainage piping located in crawl spaces.
   b. Underground piping.
   c. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

C. Indoor Piping Insulation Schedule

1. Domestic Hot and Recirculated Hot Water: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

2. Domestic Chilled Water (Potable): Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

3. Stormwater and Overflow: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

4. Roof Drain and Overflow Drain Bodies: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.
5. Exposed Sanitary Drains, Domestic Water, Domestic Hot Water, and Stops for Plumbing Fixtures for People with Disabilities: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1 inch thick.

6. Sanitary Waste Piping Where Heat Tracing Is Installed: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 1-1/2 inches thick.

D. Outdoor, Aboveground Piping Insulation Schedule
1. Domestic Water Piping: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.

2. Sanitary Waste Piping Where Heat Tracing Is Installed: Insulation shall be the following:
   a. Mineral-Fiber, Preformed Pipe Insulation, Type I: 2 inches thick.

E. Outdoor, Underground Piping Insulation Schedule

F. Indoor, Field-applied Jacket Schedule
1. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

2. If more than one material is listed, selection from materials listed is Contractor's option.

3. Equipment, Concealed:
   a. None.

4. Equipment, Exposed, up to 48 Inches in Diameter or with Flat Surfaces up to 72 Inches:
   a. Aluminum, Smooth: 0.020 inch thick.

5. Equipment, Exposed, Larger Than 48 Inches in Diameter or with Flat Surfaces Larger Than 72 Inches:

6. Piping, Concealed:
   a. None.

7. Piping, Exposed:
   a. Aluminum, Smooth: 0.020 inch thick.

G. Outdoor, Field-applied Jacket Schedule
1. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.

2. If more than one material is listed, selection from materials listed is Contractor's option.

3. Equipment, Concealed:
   a. Aluminum, Smooth: 0.020 inch thick.

4. Equipment, Exposed, up to 48 Inches in Diameter or with Flat Surfaces up to 72 Inches:
   a. Aluminum, Smooth with Z-Shaped Locking Seam: 0.024 inch thick.

5. Piping, Concealed:
   a. None.

6. Piping, Exposed:
   a. Aluminum, Smooth: 0.024 inch thick.

END OF SECTION
SECTION 22 11 16
DOMESTIC WATER PIPING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for domestic water piping inside the building.
B. Water meters will be furnished and installed by utility company.
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 22 05 00, Common Work Results for Plumbing.
   2. Section 22 05 19, Meter and Gages for Plumbing Piping.
   4. Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment.
   5. Section 22 11 19, Domestic Water Piping Specialties.
   6. Section 22 40 00, Plumbing Fixtures.
   7. Section 31 20 00, Earth Moving.
   8. Section 33 11 00, Water Utility Distribution Piping.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. ASME B16.8 Cast Copper Alloy Solder Joint Pressure Fittings
      b. ASME B16.22 Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
      c. ASME B16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500 and 2500
      a. ASTM B32 Standard Specification for Solder Metal
      b. ASTM B88 Standard Specification for Seamless Copper Water Tube
      c. ASTM B813 Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
d. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

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

4. Manufacturers Standardization Society for the Valve and Fittings Industry (MSS)
   a. MSS SP-43 Wrought and Fabricated Butt-Welding Fittings for Low Pressure, Corrosion Resistant Applications
   b. MSS SP-44 Steel Pipeline Flanges
   c. MSS SP-69 Pipe Hangers and Supports – Selection and Application
   d. MSS SP-123 Non-Ferrous Threaded and Solder-Joint Unions for Use with Copper Water Tube

5. (NSF)
   a. NSF 61 Drinking Water Components – Health Effects

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Field quality-control test reports.

1.04 QUALITY ASSURANCE
   A. Comply with NSF 61, "Drinking Water System Components - Health Effects; Sections 1 through 9," for potable domestic water piping and components.

PART 2 - PRODUCTS

2.01 PIPING MATERIALS
   A. Refer to Article 3.02, Pipe and Fitting Applications, for applications of pipe, tube, fitting, and joining materials.
   B. Transition Couplings for Aboveground Pressure Piping: Coupling or other manufactured fitting the same size as, with pressure rating at least equal to and ends compatible with, piping to be joined.
      2. Bronze Flanges: ASME B16.24, Class 150, with solder-joint ends. Furnish Class 300 flanges if required to match piping.
      3. 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.
D. Hard Copper Tube: ASTM B 88, Types L and M, water tube, drawn temper.


2. Bronze Flanges: ASME B16.24, Class 150, with solder-joint ends. Furnish Class 300 flanges if required to match piping.

3. 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.

2.02 VALVES

A. Bronze and cast-iron, general-duty valves are specified in Section 22 05 23, General-Duty Valves for Plumbing Piping.

B. Balancing and drain valves are specified in Section 22 11 19, Domestic Water Piping Specialties.

PART 3 - EXECUTION

3.01 EXCAVATION

A. Excavating, trenching, and backfilling are specified in Section 31 20 00, Earth Moving.

3.02 PIPE AND FITTING APPLICATIONS

A. Transition and special fittings with pressure ratings at least equal to piping rating may be used in applications below, unless otherwise indicated.

B. Flanges may be used on aboveground piping, unless otherwise indicated.

C. Fitting Option: Extruded-tee connections and brazed joints may be used on aboveground copper tubing.

D. Under-Building-Slab, Water-Service Piping on Service Side of Water Meter: Refer to Section 33 11 00, Water Utility Distribution Piping.

E. Domestic Water Piping on Service Side of Water Meter inside the Building: Use any of the following piping materials for each size range:

1. NPS 4 to NPS 6: Hard copper tube, Type L; copper pressure fittings; and soldered joints.

F. Under-Building-Slab, Domestic Water Piping on House Side of Water Meter, NPS 4 and Smaller: Hard copper tube, Type L; copper pressure fittings; and soldered joints.

G. Aboveground Domestic Water Piping: Use any of the following piping materials for each size range:

1. NPS 1 and Smaller: Hard copper tube, Type L; copper pressure fittings; and soldered joints.

2. NPS 1-1/4 and NPS 1-1/2: Hard copper tube, Type L; copper pressure fittings; and soldered joints.
3. NPS 2: Hard copper tube, Type L; copper pressure fittings; and soldered joints.
4. NPS 2-1/2 to NPS 3-1/2: Hard copper tube, Type L; copper pressure fittings; and soldered joints.
5. NPS 4 to NPS 6: Hard copper tube, Type L; copper pressure fittings; and soldered joints.

3.03 VALVE APPLICATIONS

A. Contract Drawings indicate valve types to be used. Where specific valve types are not indicated, the following requirements apply:
1. Shutoff Duty: Use bronze ball or gate valves for piping NPS 2 and smaller. Use cast-iron butterfly or gate valves with flanged ends for piping NPS 2-1/2 and larger.
2. Throttling Duty: Use bronze ball or globe valves for piping NPS 2 and smaller. Use cast-iron butterfly valves with flanged ends for piping NPS 2-1/2 and larger.

B. Install shutoff valve close to water main on each branch and riser serving plumbing fixtures or equipment, on each water supply to equipment, and on each water supply to plumbing fixtures that do not have supply stops. Use ball or gate valves for piping NPS 2 and smaller. Use butterfly or gate valves for piping NPS 2-1/2 and larger.

C. Install drain valves for equipment at base of each water riser, at low points in horizontal piping, and where required to drain water piping.
1. Install hose-end drain valves at low points in water mains, risers, and branches.
2. Install stop-and-waste drain valves where indicated.

D. Install calibrated balancing valves in each hot-water circulation return branch and discharge side of each pump and circulator. Set calibrated balancing valves partly open to restrict but not stop flow. Calibrated balancing valves are specified in Section 22 11 19, Domestic Water Piping Specialties

3.04 PIPING INSTALLATION

A. Basic piping installation requirements are specified in Section 22 05 00, Common Work Results for Plumbing.

B. Install under-building-slab copper tubing according to CDA's "Copper Tube Handbook."

C. Install cast-iron sleeve with water stop and mechanical sleeve seal at each service pipe penetration through foundation wall. Select number of interlocking rubber links required to make installation watertight. Sleeves and mechanical sleeve seals are specified in Section 22 05 00, Common Work Results for Plumbing.

D. Install shutoff valve, hose-end drain valve, strainer, pressure gage, and test tee with valve, inside the building at each domestic water service entrance. Pressure gages are specified in Section 22 05 19, Meter and Gages for Plumbing Piping and drain valves and strainers are specified in Section 22 11 19, Domestic Water Piping Specialties.
E. Install domestic water piping level with 0.25 percent slope downward toward drain and plumb.

3.05 JOINT CONSTRUCTION

A. Basic piping joint construction requirements are specified in Section 22 05 00, Common Work Results for Plumbing.

B. Soldered Joints: Use ASTM B 813, water-flushable, lead-free flux; ASTM B 32, lead-free-alloy solder; and ASTM B 828 procedure, unless otherwise indicated.

3.06 ROUGHING-IN FOR WATER METERS

A. Rough-in domestic water piping for water meter installation according to utility company's requirements.

B. Water meters will be furnished and installed by utility.

3.07 HANGER AND SUPPORT INSTALLATION

A. Pipe hanger and support devices are specified in Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment. Install the following:

1. Vertical Piping: MSS Type 8 or Type 42, clamps.

2. Individual, Straight, Horizontal Piping Runs: According to the following:
   a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
   b. Longer than 100 Feet: MSS Type 43, adjustable roller hangers.
   c. Longer than 100 Feet: MSS Type 49, spring cushion rolls, if indicated.

3. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.

4. Base of Vertical Piping: MSS Type 52, spring hangers.

B. Install supports according to Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment.

C. Support vertical piping and tubing at base and at each floor.

D. Rod diameter may be reduced 1 size for double-rod hangers, to a minimum of 3/8 inch.

E. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:

1. NPS 3/4 and Smaller: 60 inches with 3/8-inch rod.

2. NPS 1 and NPS 1-1/4: 72 inches with 3/8-inch rod.

3. NPS 1-1/2 and NPS 2: 96 inches with 3/8-inch rod.

4. NPS 2-1/2: 108 inches with 1/2-inch rod.

5. NPS 3 to NPS 5: 10 feet with 1/2-inch rod.

6. NPS 6: 10 feet with 5/8-inch rod.
F. Install supports for vertical copper tubing every 10 feet.

G. Support piping and tubing not listed above according to MSS SP-69 and manufacturer’s written instructions.

3.08 CONNECTIONS

A. Install piping adjacent to equipment and machines to allow service and maintenance.

B. Connect domestic water piping to exterior water-service piping. Use transition fitting to join dissimilar piping materials.

C. Connect domestic water piping to water-service piping with shutoff valve, and extend and connect to the following:
   1. Booster Pumps: Cold-water suction and discharge piping.
   2. Water Heaters: Cold-water supply and hot-water outlet piping in sizes indicated, but not smaller than sizes of water heater connections.
   3. Plumbing Fixtures: Cold- and hot-water supply piping in sizes indicated, but not smaller than required by plumbing code. Refer to Section 22 40 00, Plumbing Fixtures.
   4. Equipment: Cold- and hot-water supply piping as indicated, but not smaller than equipment connections. Provide shutoff valve and union for each connection. Use flanges instead of unions for NPS 2-1/2 and larger.

3.09 FIELD QUALITY CONTROL

A. Inspect domestic water piping as follows:
   1. Do not enclose, cover, or put piping into operation until it has been inspected and approved by authorities having jurisdiction.
   2. During installation, notify authorities having jurisdiction at least 24 hours before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction:
      a. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in and before setting fixtures.
      b. Final Inspection: Arrange final inspection for authorities having jurisdiction to observe tests specified below and to ensure compliance with requirements.
   3. Reinspection: If authorities having jurisdiction find that piping will not pass test or inspection, make required corrections and arrange for reinspection.
   4. Reports: Prepare inspection reports and have them signed by authorities having jurisdiction.

B. Test domestic water piping as follows:
   1. Fill domestic water piping. Check components to determine that they are not air bound and that piping is full of water.
2. Test for leaks and defects in new piping and parts of existing piping that have been altered, extended, or repaired. If testing is performed in segments, submit separate report for each test, complete with diagram of portion of piping tested.

3. Leave new, altered, extended, or replaced domestic water piping uncovered and unconcealed until it has been tested and approved. Expose work that was covered or concealed before it was tested.

4. Cap and subject piping to static water pressure of 50 psig above operating pressure, without exceeding pressure rating of piping system materials. Isolate test source and allow to stand for four hours and inspect. Leaks and loss in test pressure constitute defects that must be repaired.

5. Repair leaks and defects with new materials and retest piping or portion thereof until satisfactory results are obtained.

6. Prepare reports for tests and required corrective action.

3.10 CLEANING

A. Clean and disinfect potable domestic water piping using purging and disinfecting procedures prescribed by authorities having jurisdiction.

B. Prepare and submit reports of purging and disinfecting activities.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following domestic water piping specialties:
   1. Vacuum breakers.
   2. Backflow preventers.
   5. Temperature-actuated water mixing valves.
   7. Hose bibbs.
   8. Wall hydrants.
   10. Water hammer arresters.
   11. Trap-seal primer 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 22 05 00, Common Work Results for Plumbing.
   2. Section 22 05 50, Mechanical Identification.
   3. Section 22 11 16, Domestic Water Piping.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. ASME B1.20.7 Hose Coupling Screw Threads (Inch)
      b. ASME A112.1.2 Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)
      c. ASME A112.18.1 Plumbing Supply Fittings
2. American Society of Safety Engineers (ASSE)
   a. ASSE 1001 Performance Requirements for Atmospheric Type Vacuum Breakers
   b. ASSE 1003 Performance Requirements for Water Pressure Reducing Valves
   c. ASSE 1010 Performance Requirements for Water Hammer Arresters
   d. ASSE 1011 Performance Requirements for Hose Connection Vacuum Breakers
   e. ASSE 1013 Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Fire Protection Principle Backflow Preventers
   f. ASSE 1015 Performance Requirements for Double Check Backflow Prevention Assemblies and Double Check Fire Protection Backflow Prevention Assemblies
   g. ASSE 1017 Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems
   h. ASSE 1018 Performance Requirements for Trap Seal Primer Valves – Potable Water Supplied

3. American Water Works Association (AWWA)
   a. AWWA C550 Protective Epoxy Interior Coatings for Valves and Hydrants

4. Manufacturers Standardization Society for the Valve and Fittings Industry
   a. MSS SP-110 Ball Valves Threaded, Socket-Welding, Solder Joint, Grooved and Flared Ends

1.03 PERFORMANCE REQUIREMENTS
A. Minimum Working Pressure for Domestic Water Piping Specialties: 125 psig, unless otherwise indicated.

1.04 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each type of product indicated.
C. Field quality-control test reports.
D. Operation and maintenance data.

1.05 QUALITY ASSURANCE
A. NSF Compliance:

2. Comply with NSF 61, "Drinking Water System Components - Health Effects: Sections 1 through 9."

**PART 2 - PRODUCTS**

2.01 VACUUM BREAKERS

A. Hose-Connection Vacuum Breakers VB-1:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Arrowhead Brass Products, Inc.
   b. Cash Acme.
   c. Conbraco Industries, Inc.
   d. Legend Valve.
   e. MIFAB, Inc.
   f. Prier Products, Inc.
   g. Watts Industries, Inc.; Water Products Div.
   h. Woodford Manufacturing Company.
   i. Zurn Plumbing Products Group; Light Commercial Operation.
   j. Zurn Plumbing Products Group; Wilkins Div.


5. Finish: Chrome or nickel plated.

2.02 BACKFLOW PREVENTERS

A. Reduced-Pressure-Principle Backflow Preventers RPB-1:

1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

2. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Contract Drawings or a comparable product by one of the following:
   a. Ames Co.
   b. Conbraco Industries, Inc.
c. FEBCO; SPX Valves & Controls.
d. Flomatic Corporation.
e. Watts Industries, Inc.; Water Products Div.
f. Zurn Plumbing Products Group; Wilkins Div.


4. Operation: Continuous-pressure applications.

5. Pressure Loss: 12 psig maximum, through middle 1/3 of flow range.

6. Size: as shown on Contract Drawings

7. Design Flow Rate: as shown on Contract Drawings

8. Selected Unit Flow Range Limits: as shown on Contract Drawings

9. Pressure Loss at Design Flow Rate: for sizes NPS 2 and smaller; for NPS 2-1/2 and larger.

10. Body: Bronze for NPS 2 and smaller; stainless steel for NPS 2-1/2 and larger.

11. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and larger.

12. Configuration: Designed for horizontal, straight through flow.

13. Accessories:
   a. Valves: Ball type with threaded ends on inlet and outlet of NPS 2 and smaller; outside screw and yoke gate-type with flanged ends on inlet and outlet of NPS 2-1/2 and larger.

B. Double-Check Backflow-Prevention Assemblies:

   1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   
   2. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Contract Drawings or a comparable product by one of the following:
      a. Ames Co.
      b. Conbraco Industries, Inc.
      c. FEBCO; SPX Valves & Controls.
      d. Flomatic Corporation.
      e. Watts Industries, Inc.; Water Products Div.
      f. Zurn Plumbing Products Group; Wilkins Div.
4. Operation: Continuous-pressure applications, unless otherwise indicated.
5. Pressure Loss: 5 psig maximum, through middle 1/3 of flow range.
6. Pressure Loss at Design Flow Rate: 150 for sizes NPS 2 and smaller; 150 for NPS 2-1/2 and larger.
7. Body: Bronze for NPS 2 and smaller; stainless steel for NPS 2-1/2 and larger.
8. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and larger.
9. Configuration: Designed for horizontal, straight through flow.
10. Accessories:
   a. Valves: Ball type with threaded ends on inlet and outlet of NPS 2 and smaller; outside screw and yoke gate-type with flanged ends on inlet and outlet of NPS 2-1/2 and larger.

2.03 WATER PRESSURE-REDUCING VALVES

A. Water Regulators:
1. Manufacturers: Subject to compliance with requirements, provide products by one of the following:
   a. Cash Acme.
   b. Conbraco Industries, Inc.
   c. Honeywell Water Controls.
   e. Zurn Plumbing Products Group; Wilkins Div.
4. Size: line size
5. Design Inlet Pressure: 120
6. Design Outlet Pressure Setting: 60
7. Body: Bronze with chrome-plated finish for NPS 2 and smaller; cast iron with interior lining complying with AWWA C550 or that is FDA approved for NPS 2-1/2 and NPS 3.
9. End Connections: Threaded for NPS 2 and smaller; flanged for NPS 2-1/2 and NPS 3.
2.04 BALANCING VALVES

A. Memory-Stop Balancing Valves:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

2. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   a. Conbraco Industries, Inc.
   b. Crane Co.; Crane Valve Group; Crane Valves.
   c. Crane Co.; Crane Valve Group; Jenkins Valves.
   d. Crane Co.; Crane Valve Group; Stockham Div.
   e. Hammond Valve.
   f. Milwaukee Valve Company.
   g. NIBCO INC.
   h. Red-White Valve Corp.


4. Pressure Rating: 400-psig minimum CWP.

5. Size: NPS 2 or smaller.


7. Port: Standard or full port.

8. Ball: Chrome-plated brass.


10. End Connections: Solder joint or threaded.

11. Handle: Vinyl-covered steel with memory-setting device.

2.05 TEMPERATURE-ACTUATED WATER MIXING VALVES

A. Primary, Thermostatic, Water Mixing Valves:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

2. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Contract Drawings or a comparable product by one of the following:

b. Lawler Manufacturing Company, Inc.
c. Leonard Valve Company.
d. Powers; a Watts Industries Co.
e. Symmons Industries, Inc.

5. Type: Exposed-mounting, thermostatically controlled water mixing valve.
7. Connections: Threaded union inlets and outlet.
8. Accessories: Manual temperature control, check stops on hot- and cold-water supplies, and adjustable, temperature-control handle.
9. Valve Pressure Rating: 125 psig minimum, unless otherwise indicated.
10. Tempered-Water Setting: 95 degrees F
11. Valve Finish: Polished, chrome plated.
13. Cabinet: Factory-fabricated, stainless steel, for surface mounting and with hinged, stainless-steel door.

2.06 HOSE BIBBS

A. Hose Bibbs HB-1:
4. Supply Connections: NPS 1/2 or NPS 3/4 threaded or solder-joint inlet.
5. Outlet Connection: Garden-hose thread complying with ASME B1.20.7.
8. Finish for Equipment Rooms: Rough bronze, or chrome or nickel plated.
9. Finish for Service Areas: Chrome or nickel plated.
10. Finish for Finished Rooms: Chrome or nickel plated.
11. Operation for Equipment Rooms: Wheel handle or operating key.
14. Include operating key with each operating-key hose bibb.
15. Include integral wall flange with each chrome- or nickel-plated hose bibb.

2.07 WALL HYDRANTS

A. Nonfreeze Wall Hydrants WH-1:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. MIFAB, Inc.
   c. Prier Products, Inc.
   e. Tyler Pipe; Wade Div.
   f. Watts Drainage Products Inc.
   g. Woodford Manufacturing Company.
   h. Zurn Plumbing Products Group; Light Commercial Operation.
   i. Zurn Plumbing Products Group; Specification Drainage Operation.

4. Operation: Loose key.
5. Casing and Operating Rod: Of length required to match wall thickness. Include wall clamp.
6. Inlet: NPS 3/4 or NPS 1.
7. Outlet: Concealed, with integral vacuum breaker and garden-hose thread complying with ASME B1.20.7.
8. Box: Deep, flush mounting with cover.
10. Operating Keys(s): Two with each wall hydrant.

B. Moderate-Climate Wall Hydrants FH-1:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
b. MIFAB, Inc.
c. Prier Products, Inc.
e. Tyler Pipe; Wade Div.
f. Watts Drainage Products Inc.
g. Woodford Manufacturing Company.
h. Zurn Plumbing Products Group; Light Commercial Operation.
i. Zurn Plumbing Products Group; Specification Drainage Operation.


4. Operation: Loose key.

5. Inlet: NPS 3/4 or NPS 1.

6. Outlet: Concealed, with integral vacuum breaker or nonremovable hose-connection vacuum breaker complying with ASSE 1011; and garden-hose thread complying with ASME B1.20.7.

7. Box: Deep, flush mounting with cover.

8. Box and Cover Finish: Polished nickel bronze.

9. Operating Keys(s): Two with each wall hydrant.

2.08 DRAIN VALVES

A. Ball-Valve-Type, Hose-End Drain Valves:


2. Pressure Rating: 400-psig minimum CWP.


4. Body: Copper alloy.

5. Ball: Chrome-plated brass.


8. Inlet: Threaded or solder joint.

2.09 WATER HAMMER ARRESTERS

A. Water Hammer Arresters:

1. Available 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. AMTROL, Inc.
   b. Josam Company.
   c. MIFAB, Inc.
   d. PPP Inc.
   e. Sioux Chief Manufacturing Company, Inc.
   g. Tyler Pipe; Wade Div.
   h. Watts Drainage Products Inc.
   i. Zurn Plumbing Products Group; Specification Drainage Operation.


3. Type: Copper tube with piston.

4. Size: ASSE 1010, Sizes AA and A through F or PDI-WH 201, Sizes A through F.

2.10 TRAP-SEAL PRIMER VALVES

A. Supply-Type, Trap-Seal Primer Valves and system:

1. Available 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. PPP Inc.

2. Standard: ASSE 1044,

3. Piping: NPS 3/4, ASTM B 88, Type L; copper, water tubing.


5. Electric Controls: 24-hour timer, solenoid valve, and manual switch for 120-V ac power circuit breaker and tested and certified per UL#73.

6. Vacuum Breaker: ASSE 1001

7. Number Outlets: As required by the diagram and plans.
9. Manifold: copper tubing ASTM B88
12. Finish: Chrome plated, or rough bronze for units used with pipe or tube that is not chrome finished.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Refer to Section 22 05 00, Common Work Results for Plumbing, for piping joining materials, joint construction, and basic installation requirements.
B. Install backflow preventers in each water supply to mechanical equipment and systems and to other equipment and water systems that may be sources of contamination. Comply with authorities having jurisdiction.
   1. Locate backflow preventers in same room as connected equipment or system.
   2. Install drain for backflow preventers with atmospheric-vent drain connection with air-gap fitting, fixed air-gap fitting, or equivalent positive pipe separation of at least two pipe diameters in drain piping and pipe to floor drain. Locate air-gap device attached to or under backflow preventer. Simple air breaks are not acceptable for this application.
   3. Do not install bypass piping around backflow preventers.
C. Install water regulators with inlet and outlet shutoff valves and bypass with memory-stop balancing valve. Install pressure gages on inlet and outlet.
D. Install balancing valves in locations where they can easily be adjusted.
E. Install temperature-actuated water mixing valves with check stops or shutoff valves on inlets and with shutoff valve on outlet.
   1. Install thermometers and water regulators if specified.
   2. Install cabinet-type units recessed in or surface mounted on wall as specified.
F. Install Y-pattern strainers for water on supply side of each control valve, water pressure-reducing valve, solenoid valve.
G. Install water hammer arresters in water piping according to PDI-WH 201.
H. Install supply-type, trap-seal primer valves with outlet piping pitched down toward drain trap a minimum of 1 percent, and connect to floor-drain body, trap, or inlet fitting. Adjust valve for proper flow.
I. Piping installation requirements are specified in other Section 22 11 16, Domestic Water Piping, and Contract Drawings indicate general arrangement of piping and specialties.
J. **Equipment Nameplates and Signs:** Install engraved plastic-laminate equipment nameplate or sign on or near each of the following:

1. Reduced-pressure-principle backflow preventers.
2. Double-check backflow-prevention assemblies.
4. Primary, thermostatic, water mixing valves.
5. Supply-type, trap-seal primer valves.

K. Distinguish among multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations, in addition to identifying unit. Nameplates and signs are specified in Section 22 05 50, Mechanical Identification.

### 3.02 FIELD QUALITY CONTROL

A. Perform the following tests and prepare test reports:

1. Test each reduced-pressure-principle backflow preventer and double-check backflow-prevention assembly according to Seattle Public Utility and the Resident Engineer and the device’s reference standard.

B. Remove and replace malfunctioning domestic water piping specialties and retest as specified above.

### 3.03 ADJUSTING

A. Set field-adjustable pressure set points of water pressure-reducing valves.

B. Set field-adjustable flow of balancing valves.

C. Set field-adjustable temperature set points of temperature-actuated water mixing valves.

**END OF SECTION**
SECTION 22 13 16
SANITARY WASTE AND VENT PIPING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specification for the following soil and waste, sanitary drainage and vent piping inside the building:
   1. Pipe, tube, and fittings.
   2. Special pipe fittings.

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 22 05 00, Common Work Results for Plumbing.
   2. Section 22 05 23, General-Duty Valves for Plumbing Piping.
   3. Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment.
   4. Section 22 05 48, Vibration and Seismic Controls for Plumbing Piping and Equipment.
   5. Section 22 11 16, Domestic Water Piping.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society for Testing and Materials International (ASTM)
      a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
      b. ASTM A74 Standard Specification for Cast Iron Soil Pipe and Fittings
      c. ASTM A106 Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
      d. ASTM A733 Standard Specification for Welded and Seamless Carbon Steel and Austenitic Stainless Steel Pipe Nipples
      f. ASTM B32 Standard Specification for Solder Metal
g. ASTM B306 Standard Specification for Copper Drainage Tube (DWV)

h. ASTM B813 Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube

i. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

j. ASTM C564 Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings


2. American Society of Sanitary Engineering (ASSE)
   a. ASSE 1043 Performance Requirements for Cast Iron Sovent Sanitary Drainage Systems

3. Manufacturers Standardization Society (MSS)
   a. MSS SP-69 Pipe Hangers and Supports – Selection and Applications

1.03 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressure, unless otherwise indicated:


1.04 SUBMITTALS

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

B. Field quality-control inspection and test reports.

1.05 QUALITY ASSURANCE

A. Piping materials shall bear label, stamp, or other markings of an Independent Testing Laboratory.

PART 2 - PRODUCTS

2.01 PIPING MATERIALS


B. Hubless Cast-Iron Pipe and Fittings: ASTM A 888 or CISPI 301.

   1. Sovent Stack Fittings: ASME B16.45 or ASSE 1043, hubless, cast-iron aerator and deaerator drainage fittings.

   2. Shielded Couplings: ASTM C 1277 assembly of metal shield or housing, corrosion-resistant fasteners, and rubber sleeve with integral, center pipe stop.
a. **Heavy-Duty, Shielded, Stainless-Steel Couplings:** With stainless-steel shield, stainless-steel bands and tightening devices, and ASTM C 564, rubber sleeve.

C. **Steel Pipe:** ASTM A 53/A 53M, Type E or S, Grade A or B, Schedule 40, galvanized. Include ends matching joining method.

1. **Drainage Fittings:** ASME B16.12, galvanized, threaded, cast-iron drainage pattern.

2. **Pressure Fittings:**
   a. **Steel Pipe Nipples:** ASTM A 733, made of ASTM A 53/A 53M or ASTM A 106, Schedule 40, galvanized, seamless steel pipe. Include ends matching joining method.
   b. **Malleable-Iron Unions:** ASME B16.39; Class 150; hexagonal-stock body with ball-and-socket, metal-to-metal, bronze seating surface; and female threaded ends.
   c. **Gray-Iron, Threaded Fittings:** ASME B16.4, Class 125, galvanized, standard pattern.
   d. **Cast-Iron Flanges:** ASME B16.1, Class 125.
   e. **Cast-Iron, Flanged Fittings:** ASME B16.1, Class 125, galvanized.

D. **Copper DWV Tube:** ASTM B 306, drainage tube, drawn temper.

1. **Copper Drainage Fittings:** ASME B16.23, cast copper or ASME B16.29, wrought-copper, solder-joint fittings.

**PART 3 - EXECUTION**

3.01 **PIPING APPLICATIONS**

A. Special pipe fittings with pressure ratings at least equal to piping pressure ratings may be used in applications below, unless otherwise indicated.

B. Flanges and unions may be used on aboveground pressure piping, unless otherwise indicated.

C. Aboveground, soil, waste, and vent piping NPS 4 and smaller shall be any of the following:

1. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

2. Copper DWV tube, copper drainage fittings, and soldered joints.

D. Aboveground, soil, waste, and vent piping NPS 5 and larger shall be any of the following:

1. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

2. Copper DWV tube, copper drainage fittings, and soldered joints.
E. Underground, soil, waste, and vent piping NPS 4 and smaller shall be any of the following:

1. Service class, hub-and-spigot, cast-iron soil pipe and fittings; gaskets; and compression joints.
2. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

F. Underground, soil and waste piping NPS 5 and larger shall be any of the following:

1. Service class, cast-iron soil pipe and fittings; gaskets; and compression joints.
2. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

3.02 PIPING INSTALLATION

A. Sanitary sewer piping outside the building is specified in Section 22 13 16, Sanitary Waste and Vent Piping.

B. Basic piping installation requirements are specified in Section 22 05 00, Common Work Results for Plumbing.

C. Install cleanouts at grade and extend to where building sanitary drains connect to building sanitary sewers.

D. Install cast-iron sleeve with water stop and mechanical sleeve seal at each service pipe penetration through foundation wall. Select number of interlocking rubber links required to make installation watertight. Sleeves and mechanical sleeve seals are specified in Section 22 05 00, Common Work Results for Plumbing.


F. Make changes in direction for soil and waste drainage and vent piping using appropriate branches, bends, and long-sweep bends. Sanitary tees and short-sweep 1/4 bends may be used on vertical stacks if change in direction of flow is from horizontal to vertical. Use long-turn, double Y-branch and 1/8-bend fittings if two fixtures are installed back to back or side by side with common drain pipe. Straight tees, elbows, and crosses may be used on vent lines. Do not change direction of flow more than 90 degrees. Use proper size of standard increasers and reducers if pipes of different sizes are connected. Reducing size of drainage piping in direction of flow is prohibited.

G. Lay buried building drainage piping beginning at low point of each system. Install true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets according to manufacturer’s written instructions for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.

H. Install soil and waste drainage and vent piping at the following minimum slopes, unless otherwise indicated:

1. Building Sanitary Drain: 2 percent downward in direction of flow for piping NPS 3 and smaller; 1 percent downward in direction of flow for piping NPS 4 and larger.
2. Horizontal Sanitary Drainage Piping: 2 percent downward in direction of flow.
3. Vent Piping: 1 percent down toward vertical fixture vent or toward vent stack.

I. Sleeves are not required for cast-iron soil piping passing through concrete slabs-on-grade if slab is without membrane waterproofing.

J. Do not enclose, cover, or put piping into operation until it is inspected and approved by authorities having jurisdiction.

3.03 JOINT CONSTRUCTION

A. Basic piping joint construction requirements are specified in Section 22 05 00, Common Work Results for Plumbing.


   1. Gasketed Joints: Make with rubber gasket matching class of pipe and fittings.
   2. Hubless Joints: Make with rubber gasket and sleeve or clamp.

C. Soldered Joints: Use ASTM B 813, water-flushable, lead-free flux; ASTM B 32, lead-free-alloy solder; and ASTM B 828 procedure, unless otherwise indicated.

3.04 VALVE INSTALLATION

A. General-duty valves are specified in Section 22 05 23, General-Duty Valves for Plumbing Piping.

B. Shutoff Valves: Install shutoff valve on each sewage pump discharge.

   1. Use gate or full-port ball valve for piping NPS 2 and smaller.
   2. Use gate valve for piping NPS 2-1/2 and larger.

C. Check Valves: Install swing check valve, downstream from shutoff valve, on each sewage pump discharge.

D. Backwater Valves: Install backwater valves in piping subject to sewage backflow.

   1. Horizontal Piping: Horizontal backwater valves. Use normally closed type, unless otherwise indicated.
   2. Floor Drains: Drain outlet backwater valves, unless drain has integral backwater valve.
   3. Install backwater valves in accessible locations.
   4. Backwater valves are specified in Section 22 13 19, Sanitary Waste Piping Specialties.

3.05 HANGER AND SUPPORT INSTALLATION

A. Seismic-restraint devices are specified in Section 22 05 48, Vibration and Seismic Controls for Plumbing Piping and Equipment.

B. Pipe hangers and supports are specified in Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment:
1. Vertical Piping: MSS Type 8 or Type 42, clamps.

2. Individual, Straight, Horizontal Piping Runs: According to the following:
   a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
   b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
   c. Longer Than 100 Feet, if Indicated: MSS Type 49, spring cushion rolls.

3. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.

4. Base of Vertical Piping: MSS Type 52, spring hangers.

C. Install supports according to Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment.

D. Support vertical piping and tubing at base and at each floor.

E. Rod diameter may be reduced one size for double-rod hangers, with 3/8-inch minimum rods.

F. Install hangers for cast-iron soil piping with the following maximum horizontal spacing and minimum rod diameters:
   1. NPS 1-1/2 and NPS 2: 60 inches with 3/8-inch rod.
   2. NPS 3: 60 inches with 1/2-inch rod.
   3. NPS 4 and NPS 5: 60 inches with 5/8-inch rod.
   4. NPS 6: 60 inches with 3/4-inch rod.
   5. Spacing for 10-foot lengths may be increased to 10 feet. Spacing for fittings is limited to 60 inches.

G. Install supports for vertical cast-iron soil piping every 15 feet.

H. Install hangers for steel piping with the following maximum horizontal spacing and minimum rod diameters:
   1. NPS 1-1/4: 84 inches with 3/8-inch rod.
   2. NPS 1-1/2: 108 inches with 3/8-inch rod.
   3. NPS 2: 10 feet with 3/8-inch rod.
   4. NPS 2-1/2: 11 feet with 1/2-inch rod.
   5. NPS 3: 12 feet with 1/2-inch rod.
   6. NPS 4 and NPS 5: 12 feet with 5/8-inch rod.
   7. NPS 6: 12 feet with 3/4-inch rod.

I. Install supports for vertical steel piping every 15 feet.
J. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:

1. NPS 1-1/4: 72 inches with 3/8-inch rod.
2. NPS 1-1/2 and NPS 2: 96 inches with 3/8-inch rod.
3. NPS 2-1/2: 108 inches with 1/2-inch rod.
4. NPS 3 to NPS 5: 10 feet with 1/2-inch rod.
5. NPS 6: 10 feet with 5/8-inch rod.

K. Install supports for vertical copper tubing every 10 feet.

L. Support piping and tubing not listed above according to MSS SP-69 and manufacturer's written instructions.

3.06 CONNECTIONS

A. Connect soil and waste piping to exterior sanitary sewerage piping. Use transition fitting to join dissimilar piping materials.

B. Connect drainage and vent piping to the following:

1. Plumbing Fixtures: Connect drainage piping in sizes indicated, but not smaller than required by plumbing code. Refer to Section 22 13 19, Sanitary Waste Piping Specialties.

2. Plumbing Fixtures and Equipment: Connect atmospheric vent piping in sizes indicated, but not smaller than required by authorities having jurisdiction.

3. Plumbing Specialties: Connect drainage and vent piping in sizes indicated, but not smaller than required by plumbing code. Refer to Section 22 13 19, Sanitary Waste Piping Specialties.

4. Equipment: Connect drainage piping as indicated. Provide shutoff valve, if indicated, and union for each connection. Use flanges instead of unions for connections NPS 2-1/2 and larger.

3.07 FIELD QUALITY CONTROL

A. During installation, notify Resident Engineer at least 24 hours before inspection must be made. Perform tests specified below in presence of Resident Engineer and the Seattle Public Utility authority.

1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in and before setting fixtures.

2. Final Inspection: Arrange for final inspection by Resident Engineer and the Seattle Public Utility authority to observe tests specified below and to ensure compliance with requirements.

B. Reinspection: If Resident Engineer and the Seattle Public Utility authority find that piping will not pass test or inspection, make required corrections and arrange for reinspection.

C. Reports: Prepare inspection reports and have them signed by Resident Engineer and the Seattle Public Utility authority.
D. Test sanitary drainage and vent piping according to manufactures procedures of Resident Engineer and the Seattle Public Utility authority.

1. Repair leaks and defects with new materials and retest piping, or portion thereof, until satisfactory results are obtained.

2. Prepare reports for tests and required corrective action.

3.08 CLEANING

A. Clean interior of piping. Remove dirt and debris as work progresses.

B. Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.

C. Place plugs in ends of uncompleted piping at end of day and when work stops.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 22 13 19
SANITARY WASTE PIPING SPECIALTIES

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specification for the following sanitary drainage piping specialties:
   1. Cleanouts.
   2. Floor drains.
   3. Roof flashing assemblies.
   5. Flashing 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 07 62 00, Sheet Metal Flashing and Trim.
   2. Section 22 05 00, Common Work Results for Fire Suppression.
   3. Section 22 05 50, Mechanical Identification.

1.02 REFERENCES
A. This Section incorporates by reference the latest revision of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. ASME A112.1.2 Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)
      b. ASME A112.6.3 Floor and Trench Drains
      c. ASME A112.14.1 Backwater Valves
      d. ASME A112.14.3 Grease Interceptors
      e. ASME A112.36.2M Cleanouts
      a. ASTM A74  Standard Specification for Cast Iron Soil Pipe and Fittings
      b. ASTM B32  Standard Specification for Solder Metal
c. ASTM C564 Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings

1.03 SUBMITTALS

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

B. Product Data: For each type of product indicated. Include rated capacities, operating characteristics, and accessories for grease interceptors.

1.04 QUALITY ASSURANCE

A. Drainage piping specialties shall bear label, stamp, or other markings of an Independent Testing Laboratory.

PART 2 - PRODUCTS

2.01 CLEANOUTS

A. Exposed Cast-Iron Cleanouts:

   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

      c. Tyler Pipe; Wade Div.
      d. Zurn Plumbing Products Group; Specification Drainage Operation.

   2. Standard: ASME A112.36.2M for cast iron for cleanout test tee.

   3. Size: Same as connected drainage piping


   5. Closure: Countersunk or raised-head, cast-iron plug.

   6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.

B. Cast-Iron Floor Cleanouts:

   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

      c. Tyler Pipe; Wade Div.
d. Zurn Plumbing Products Group; Light Commercial Operation.
e. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.36.2M for cast-iron soil pipe with cast-iron ferrule heavy-duty, adjustable housing cleanout.

3. Size: Same as connected branch.

4. Type: Cast-iron soil pipe with cast-iron ferrule Heavy-duty, adjustable housing.

5. Body or Ferrule: Cast iron.


7. Outlet Connection: Spigot.

8. Closure: Cast-iron plug.

9. Adjustable Housing Material: Cast iron with threads.


11. Frame and Cover Shape: Square.

12. Top Loading Classification: Extra Heavy Duty.

13. Riser: ASTM A 74, Extra-Heavy class, cast-iron drainage pipe fitting and riser to cleanout.

C. Cast-Iron Wall Cleanouts:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   c. Tyler Pipe; Wade Div.
   d. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.36.2M. Include wall access.

3. Size: Same as connected drainage piping.


5. Closure: Countersunk or raised-head, cast-iron plug.

6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.

2.02 FLOOR DRAINS

A. Cast-Iron Floor Drains: FD-1, FD-2, AD-1

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. Prier Products, Inc.
   d. Tyler Pipe; Wade Div.
   e. Zurn Plumbing Products Group; Light Commercial Operation.
   f. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.6.3 with backwater valve.
3. Pattern: Area drain heel proof.
5. Seepage Flange: Required.
6. Anchor Flange: Required.
7. Clamping Device: Required.
8. Outlet: Bottom.
12. Top or Strainer Material: Gray iron.
14. Top Shape: Square.
15. Dimensions of Top or Strainer: scheduled
17. Funnel: Required if scheduled.
18. Inlet Fitting: Gray iron, with threaded inlet and threaded or spigot outlet, and trap-seal primer valve connection.
21. Trap Features: Cleanout and trap-seal primer valve drain connection.
B. Cast-Iron Area Drains: AD-1

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. Prier Products, Inc.
   d. Tyler Pipe; Wade Div.
   e. Zurn Plumbing Products Group; Light Commercial Operation.
   f. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.6.3 with backwater valve.

3. Pattern: Area drain heel proof.


5. Seepage Flange: Required.

6. Anchor Flange: Required.

7. Clamping Device: Required.

8. Outlet: Bottom.


11. Top or Strainer Material: Gray iron.


13. Top Shape: Square.

14. Dimensions of Top or Strainer: scheduled

15. Top Loading Classification: Extra Heavy-Duty.

16. Inlet Fitting: Gray iron, with threaded inlet and threaded or spigot outlet, and trap-seal primer valve connection.

2.03 ROOF FLASHING ASSEMBLIES

A. Roof Flashing Assemblies:

1. Available 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. Acorn Engineering Company; Elmdor/Stoneman Div.
b. Thaler Metal Industries Ltd.

B. Description: Manufactured assembly made of 6.0-lb/sq. ft., 0.0938-inch- thick, lead flashing collar and skirt extending at least 10 inches from pipe, with galvanized-steel boot reinforcement and counterflashing fitting.


2.04 MISCELLANEOUS SANITARY DRAINAGE PIPING SPECIALTIES

A. Open Drains:

1. Description: Shop or field fabricate from ASTM A 74, Service class, hub-and-spigot, cast-iron, soil-pipe fittings. Include P-trap, hub-and-spigot riser section; and where required, increaser fitting joined with ASTM C 564, rubber gaskets.

2. Size: Same as connected waste piping with increaser fitting of size indicated.

B. Deep-Seal Traps:

1. Description: Cast-iron or bronze casting, with inlet and outlet matching connected piping and cleanout trap-seal primer valve connection.

2. Size: Same as connected waste piping.
   a. NPS 2: 4-inch- minimum water seal.
   b. NPS 2-1/2 and Larger: 5-inch- minimum water seal.

C. Floor-Drain, Trap-Seal Primer Fittings:

1. Description: Cast iron, with threaded inlet and threaded or spigot outlet, and trap-seal primer valve connection.

2. Size: Same as floor drain outlet with NPS 1/2 side inlet.

D. Air-Gap Fittings:

1. Standard: ASME A112.1.2, for fitting designed to ensure fixed, positive air gap between installed inlet and outlet piping.

2. Body: Bronze or cast iron.

3. Inlet: Opening in top of body.

4. Outlet: Larger than inlet.

5. Size: Same as connected waste piping and with inlet large enough for associated indirect waste piping.

E. Sleeve Flashing Device:

1. Description: Manufactured, cast-iron fitting, with clamping device that forms sleeve for pipe floor penetrations of floor membrane. Include galvanized-steel pipe extension in top of fitting that will extend 2 inches above finished floor and
galvanized-steel pipe extension in bottom of fitting that will extend through floor slab.

2. Size: As required for close fit to riser or stack piping.

F. Stack Flashing Fittings:

1. Description: Counterflashing-type, cast-iron fitting, with bottom recess for terminating roof membrane, and with threaded or hub top for extending vent pipe.
2. Size: Same as connected stack vent or vent stack.

G. Vent Caps:

1. Description: Cast-iron body with threaded or hub inlet and vandal-proof design. Include vented hood and setscrews to secure to vent pipe.
2. Size: Same as connected stack vent or vent stack.

2.05 FLASHING MATERIALS

A. Lead Sheet: ASTM B 749, Type L51121, copper bearing, with the following minimum weights and thicknesses, unless otherwise indicated:

1. General Use: 4.0-lb/sq. ft., 0.0625-inch thickness.
2. Vent Pipe Flashing: 3.0-lb/sq. ft., 0.0469-inch thickness.

B. Fasteners: Metal compatible with material and substrate being fastened.

C. Metal Accessories: Sheet metal strips, clamps, anchoring devices, and similar accessory units required for installation; matching or compatible with material being installed.

D. Solder: ASTM B 32, lead-free alloy.

E. Bituminous Coating: SSPC-Paint 12, solvent-type, bituminous mastic.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Refer to Section 22 05 00, Common Work Results Plumbing.

B. For piping joining materials, joint construction, and basic installation requirements.

C. Install backwater valves in building drain piping. For interior installation, provide cleanout deck plate flush with floor and centered over backwater valve cover, and of adequate size to remove valve cover for servicing.

D. Install cleanouts in aboveground piping and building drain piping according to the following, unless otherwise indicated:

1. Size same as drainage piping up to NPS 4. Use NPS 4 for larger drainage piping unless larger cleanout is indicated.
2. Locate at each change in direction of piping greater than 45 degrees.
3. Locate at minimum intervals of 50 feet for piping NPS 4 and smaller and 100 feet for larger piping.

4. Locate at base of each vertical soil and waste stack.

E. For floor cleanouts for piping below floors, install cleanout deck plates with top flush with finished floor.

F. For cleanouts located in concealed piping, install cleanout wall access covers, of types indicated, with frame and cover flush with finished wall.

G. Install floor drains at low points of surface areas to be drained. Set grates of drains flush with finished floor, unless otherwise indicated.
   1. Position floor drains for easy access and maintenance and see architectural floor layouts for finishes.
   2. Set floor drains below elevation of surrounding finished floor to allow floor drainage. Set with grates depressed according to the following drainage area radii:
      a. Radius, 30 Inches or Less: Equivalent to 1 percent slope, but not less than 1/4-inch total depression.
      b. Radius, 30 to 60 Inches: Equivalent to 1 percent slope.
      c. Radius, 60 Inches or Larger: Equivalent to 1 percent slope, but not greater than 1-inch total depression.
   3. Install floor-drain flashing collar or flange so no leakage occurs between drain and adjoining flooring. Maintain integrity of waterproof membranes where penetrated.
   4. Install individual traps for floor drains connected to sanitary building drain, unless otherwise indicated.

H. Install roof flashing assemblies on sanitary stack vents and vent stacks that extend through roof.

I. Install flashing fittings on sanitary stack vents and vent stacks that extend through roof.

J. Assemble open drain fittings and install with top of hub 2 inches above floor.

K. Install deep-seal traps on floor drains and other waste outlets, if indicated.

L. Install floor-drain, trap-seal primer fittings on inlet to floor drains that require trap-seal primer connection.
   1. Exception: Fitting may be omitted if trap has trap-seal primer connection.
   2. Size: Same as floor drain inlet.

M. Install air-gap fittings on draining-type backflow preventers and on indirect-waste piping discharge into sanitary drainage system.

N. Install sleeve flashing device with each riser and stack passing through floors with waterproof membrane.

O. Install vent caps on each vent pipe passing through roof.
P. Install grease interceptors, including trapping, venting, and flow-control fitting, according to authorities having jurisdiction and with clear space for servicing.

1. Above-Floor Installation: Set unit with bottom resting on floor, unless otherwise indicated.

2. Flush with Floor Installation: Set unit and extension, if required, with cover flush with finished floor.

3. Recessed Floor Installation: Set unit in receiver housing having bottom or cradle supports, with receiver housing cover flush with finished floor.

4. Install cleanout immediately downstream from interceptors not having integral cleanout on outlet.

Q. Install traps on plumbing specialty drain outlets. Omit traps on indirect wastes unless trap is indicated.

R. Install escutcheons at wall, floor, and ceiling penetrations in exposed finished locations and within cabinets and millwork. Use deep-pattern escutcheons if required to conceal protruding pipe fittings.

3.02 CONNECTIONS

A. Piping installation requirements are specified in other Division 22, Plumbing, Sections. Contract Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to equipment to allow service and maintenance.

3.03 FLASHING INSTALLATION

A. Fabricate flashing from single piece unless large pans, sumps, or other drainage shapes are required. Join flashing according to the following if required:

1. Lead Sheets: Burn joints of lead sheets 6.0-lb/sq. ft., 0.0938-inch thickness or thicker. Solder joints of lead sheets 4.0-lb/sq. ft., 0.0625-inch thickness or thinner.

B. Install sheet flashing on pipes, sleeves, and specialties passing through or embedded in floors and roofs with waterproof membrane.

1. Pipe Flashing: Sleeve type, matching pipe size, with minimum length of 10 inches, and skirt or flange extending at least 8 inches around pipe.

2. Sleeve Flashing: Flat sheet, with skirt or flange extending at least 8 inches around sleeve.

3. Embedded Specialty Flashing: Flat sheet, with skirt or flange extending at least 8 inches around specialty.

C. Set flashing on floors and roofs in solid coating of bituminous cement.

D. Secure flashing into sleeve and specialty clamping ring or device.

E. Install flashing for piping passing through roofs with counter flashing or commercially made flashing fittings, according to Section 07 62 00, Sheet Metal Flashing and Trim.
F. Extend flashing up vent pipe passing through roofs and turn down into pipe, or secure flashing into cast-iron sleeve having calking recess.

3.04 LABELING AND IDENTIFYING

A. Equipment Nameplates and Signs: Install engraved plastic-laminate equipment nameplate or sign on or near each grease interceptor.

B. Distinguish among multiple units, inform operator of operational requirements, indicate safety and emergency precautions, and warn of hazards and improper operations, in addition to identifying unit. Nameplates and signs are specified in Section 22 05 50, Mechanical Identification.

3.05 PROTECTION

A. Protect drains during remainder of construction period to avoid clogging with dirt or debris and to prevent damage from traffic or construction work.

B. Place plugs in ends of uncompleted piping at end of each day or when work stops.

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.

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 22 14 10, Pumping Station Piping and Appurtenances.

1.02 REFERENCES

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

   1. American Society for Testing and Materials International (ASTM)
      b. ASTM A74 Standard Specification for Cast Iron Soil Pipe and Fittings
      c. ASTM D653 Standard Terminology Relating to Soil, Rock, and Contained Fluids
      d. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120

   2. International Plumbing Code and local amendments

1.03 SUBMITTALS

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

B. Submit shop drawings showing piping layouts, sizes, types, valves, drains, and cleanouts.

C. Submit manufacturers’ product data for specified materials and equipment.

D. Submit 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. Submit certified test results and certificates of compliance as necessary to verify conformance with specified requirements.
1.04 PROJECT CONDITIONS

A. Install drainage piping on surfaces and structures capable of supporting the piping. Prior to installation verify tunnel gradient and conditions provide positive flow through the track drainage piping to the low point pump station.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings

1. General: Provide pipe and fittings of sizes and configurations indicated. Provide cast iron ASTM A74 pipe and fittings for nonpressure piping.

2. Use Polyvinyl chloride (PVC), ASTM D1785, Schedule 80, Type I, Grade 1 for embedded track drainage piping.
   a. Fittings: Same material and schedule as pipe.

B. Drainage Inlets

1. General: Drainage inlets include a galvanized sheet pan, grate and frame as detailed on the Contract Drawings.

2. Sheet Metal Pan: 16 gauge sheet metal, galvanized to meet ASTM A653 G90.

3. Grate and Frame: Cast iron body, heavy-duty.

C. Gutter and Trench Drains

1. Provide gutter and trench drains manufactured of heavy cast iron with double drainage patterns, sediment bucket, integral seepage pan and trap primer connection. Provide strainer of chrome plated, cast brass, polished brass or buff polished nickel alloy, as indicated, attached to a brass threaded collar for adjustment to varying floor thicknesses. Provide cast iron, extra heavy traffic pattern gutter or trench drains, where indicated.

D. Cleanouts

1. Size and select cast iron cleanouts conforming to ASTM A48, Class 25B.

2. Install adjustable type floor cleanouts that have scoriated nickel alloy cover and membrane clamping device.

3. Select bolted, wedge type wall cleanouts which have a cover. Select a stainless steel cover plate that can be mounted in a flanged frame and secured to the plug with a vandal-proof screw.

4. Install exposed cleanouts with a raised brass head cleanout plug.

5. Install grade cleanouts with an adjustable sleeve housing, with a threaded brass plug and a countersunk slot.

E. Access Covers and Frames
PART 3 - EXECUTION

3.01 PREPARATION

A. Prior to installing or placing drainage products, insure excavations are free from water and extraneous material immediately therein.
B. Clean interior of pipe, pipe fittings, drains, and cleanouts before installation.
C. Install sleeves through walls, floors, roofs, and other structures before drainage lines are installed.

3.02 INSTALLATION

A. Install track drainage piping as detailed on the Contract Drawings.
B. Install cleanouts which are the same size as the pipe up to and including 4 inches, 6 inches and larger with 4 inches as a minimum. Cleanouts for drainage pipe include, a long-sweep 1/4 bend or one or two 1/8 bends extended to the place indicated. Use T-pattern, 90-degree branch drainage fittings with screw plugs for wall or accessible piping cleanouts.

3.03 FIELD QUALITY CONTROL

A. Testing

1. Do not cover products to be embedded in concrete until inspections, testing, and acceptance of those products have occurred.
2. Test installed storm drainage lines and equipment as follows:
   a. Fill gravity storm drains with water and allow to stand for not less than 30 minutes without leaking; temporarily seal low and intermediate branches. If the storm drain is to be tested in sections, Provide test tees having cast iron screwed plugs in the vertical stacks. Finish testing of interior lines before lines are concealed. Repair leaks and retest systems until the system exhibits no leaks. Test with a water head between 22 and 30 feet for testing integrity of pipe.

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.
B. It is the contractor’s responsibility to apply for and secure all permits required by the City of Seattle and the Seattle Public Utility to drain into sewer or storm systems.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing the tunnel track drainage pumping station piping and appurtenances indicated on the Contract Drawings and within this Contract Specification.

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 22 05 29, Hangers and Supports for Plumbing Piping and Equipment
2. 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 of Mechanical Engineers (ANSI)
   a. ANSI A13.1 Scheme for Identification of Piping Systems
   b. ANSI B16.1 Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125 and 250
   c. ANSI B18.5 Round Head Bolts (Inch Series)
   d. ANSI B18.10 Track Bolts and Nuts
   e. ANSI B18.22 Plain Washers
   f. ANSI B31.1 Power Piping and Process Piping SET
   g. ANSI B40.1 Gauges – Pressure Indicating Dial Type – Elastic Element

   b. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless
   c. ASTM A58 Standard Specification for Pipe, Steel, Black and Hot Dipped, Zinc Coated, Welded and Seamless
   d. ASTM A112 Moisture-Induced Stress Sensitivity for Plastic Surface Mount Devices

f. ASTM A153 Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

g. ASTM A164 ASTM Dictionary of Engineering Science and Technology

h. ASTM A536 Standard Specification for Ductile Iron Castings

i. ASTM B127 Standard Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet and Strip

j. ASTM D2000 Standard Classification System for Rubber Products in Automotive Applications

3. US Federal Specifications (Fed. Spec.)
   a. Fed. Spec. FF-S-325 - Shield, Expansion; Nail Expansion, and Nail, Drive Screw (Devices, Anchoring, Masonry)
   c. Fed. Spec. WW-P-421 - Pipe, Cast Gray Ductile Iron, Pressure (for Water and Other

4. Hydraulic Institute Standards (HI)
   a. ANSI/HI 9.8 Centrifugal and Vertical Pump Intake Design
   b. ANSI/HI 11.6 Submersible Pump Tests

5. American Water Works Association (AWWA)
   a. AWWA C104 Cement-Mortar Lining for Ductile-Iron Pipe and Fittings
   b. AWWA C110 Ductile-Iron and Gray-Iron Fittings for Water
   c. AWWA C111 Rubber gasket Joints for Ductile Iron Pressure Pipe & Fittings
   d. AWWA C115 Standard for Flanged Ductile-Iron Pipe With Threaded Flanges
   e. AWWA C150 Thickness Design of Ductile-Iron Pipe
   f. AWWA C151 American National Standard for Ductile-Iron Pipe, Centrifugally Cast, for Water
   g. AWWA C153 Ductile-Iron Compact Fittings for Water Service
   h. AWWA C210 Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines
   i. AWWA C600 Installation of Ductile-Iron Water Mains and Their Appurtenances
   j. AWWA C606 Grooved and Shouldered Joints
6. Manufacturers Standardization Society (MSS)
   a. MSS SP-58 Pipe Hangers and Supports – Materials, Design and Manufacture
   b. MSS SP-69 Pipe Hangers and Supports – Selection and Application

1.03 SUBMITTALS

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

B. Submit the following four weeks prior to starting construction of the initial lining for the concrete wet well at the low-point cross passage pump station:

1. Calculations for pipe support or manufacturers load capacity data.

2. Manufacturer’s Data. Submit manufacturer’s standard drawings or 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. Floor hatches (including hardware)
   h. Manufacturer’s installation instructions.

3. 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. 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.

4. Manufacturer’s operation and maintenance material and manuals, in accordance with Section 33 01 00, Operation and Maintenance of Utilities.

1.04 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 PIPE AND FITTINGS

A. Furnish all pipe, fittings, and appurtenances as indicated on Contract Drawings and specified in this Section. For all pipe, fittings, valves, and appurtenances use only new products.

B. Non-Buried Pipe:

1. Located within the pump station, inside the wet well and the cross passage.

2. Grade C ductile iron pipe conforming to 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 with coal tar epoxy, minimum 20 mil thick on the exterior surface of the pipe.

5. Flanged pipe:
   a. AWWA C115.

6. Cement mortar lining conforming to AWWA C210 Type V cement.

C. Non-Buried Joints:

1. Mechanical grooved type joints or flange joints with screwed on ductile iron flanges where required for connection to flanged valves.

2. Flanges that meet the requirements of AWWA Standard C115.


4. Field made-up flanges will not be allowed.

D. Non-Buried Fittings:

1. Designed and manufactured fittings 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 conforming to 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 conforming to AWWA C210 Type V cement.
6. Factory furnished exterior coating equal to that of the connecting pipe.

E. Buried Pipe and Fittings:

1. Used for the buried storm water pumped discharge piping system, including the inter-tie piping between tunnels.
2. made up of restrained push-on joint pipe and fittings utilizing ductile iron components
   a. Restrained joint pipe:
      1) Ductile Iron manufactured in accordance with the requirements of ANSI/AWWA C151/A21.51.
      2) Push-on joints in accordance with ANSI/AWWA C111/A21.11
      3) Nominal thickness conforming to ANSI/AWWA C150/21.50 for working pressures to 350 psi and laying conditions as indicated on Contract Drawings.
   b. Restrained joint fittings and the restraining components: Ductile iron in accordance with the applicable requirements of ANSI/AWWA C110/A21.10 or C153/A21.53 with the exception of design dimensions specific to each manufacturer’s product.
   c. Cement Mortar lining and seal coating for pipe and fittings:
      1) ANSI/AWWA C104/A21.4.
      2) Outside coated in accordance with AWWA C210 and as described in Article 2.01 F herein.
   d. Acceptable manufactures of restrained joint pipe and fittings:
      1) TR-FLEX pipe and fittings, as manufactured by US Pipe
      2) Lok-Ring as manufactured by American Ductile Iron Pipe
      3) Approved equal.

F. Pipe Coating:

1. Applied to the exterior surfaces of the pipe in accordance with AWWA C210:
   a. Surface preparation: Solvent Clean (SSPC-SP-1) followed by abrasive blast-cleaning to Near White Metal (SSPC-SP-10) with an anchor profile between 3 and 4 mils.
b. Two uniform coats of coal tar epoxy conforming to AWWA C210: Applied to a total dry film thickness of 20 to 30 mils.

c. Drying time between coats: 12 hours minimum, 24 hours maximum at 70 degrees F. Inter-coat drying time is critical. Dry according to manufacturer's recommendations.

G. Fabricated Wall Pipe:

1. Ductile iron
2. Provided grooved end by plain end
3. Of lengths as indicated on the Contract Drawings, complete with intermediate flange fabricated from hot rolled steel
4. Of the same thickness class, exterior coating and interior lining as the connecting pipe.

H. Non-Buried Groove-Type Mechanical Couplings:

1. 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.
2. Provide a rigid joint comparable to a flanged system.
3. Clamp housing:
   a. Consist of two or more parts
   b. Made of ductile iron conforming to ASTM A 536.
   c. Bolts and nuts for connecting clamp housing connections:
      1) Track bolts and nuts conforming to ANSI B18.10
      2) Roundhead, square neck type conforming to ANSI B18.5
      3) Hex nuts conforming to ANSI B18.22;
      4) Zinc plated to ASTM A 164.
   d. Bolt holes: of a shape to hold fast the necks of the bolts used
4. Gaskets:
   a. Molded nitrile synthetic rubber, flush seal type, conforming to ASTM D 2000
   b. Supplied by the coupling vendor.
   c. Shaped to effectively seal joint against leakage, when compressed.
5. Grooved ends of piping: In accordance with the published recommendations of the manufacturer of the coupling, as approved by the Resident Engineer.
6. Strength of coupling: Not less than that of the pipe.
7. Covered with factory applied, 3 mil thick, coal tar epoxy coating.

I. Groove-Type Mechanical Flange Adapters:

1. Used to join fittings with grooved ends to flanged pipe and fittings.
2. Engage groove in pipe or fitting and hold this end to the adjoining flange to form a rigid, watertight joint.
3. Clamp housing: Consisting of two or more parts made of malleable iron conforming to ASTM A 536.
5. Gasket: Nitrile and supplied by the flange adapter manufacturer.
6. Flange washer: Used between the flange adapter gasket and the flange or flange gasket if so stipulated by the adapter manufacturer.
7. Flange: Conform to ANSI B16.1: Class 125 drilling.
8. Coating of the flange adapters: Equal to the approved coating for the grooved couplings

J. Flange Joint Accessories:

1. Gaskets for flange joints:
   b. Full face
   c. 1/8-inch thickness neoprene.

2.02 VALVES

A. Furnish all isolation, check and drain valves, shown on the discharge side of the sump pumps, as indicated on the Contract Drawings and specified herein.

B. Plug Valves:

1. Eccentric plug type unless otherwise specified herein or indicated on Contract Drawings.
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 insure that the plug face contacts only nickel.

3. Plug:
   a. ASTM A 126 Class B cast iron.
   b. Have a cylindrical seating surface eccentrically offset from the plug shaft.
   c. Have interference between the plug face and the body seat that is externally adjustable in the field with the valve in the line under pressure.

4. Sleeve type metal bearings of sintered, oil impregnated, permanently lubricated, type 316, stainless steel.
   a. Stem seals:
      1) Multi-V ring adjustable packing type
      2) Replaceable in-line without valve disassembly.

5. Port area: Not be less than 80 percent of the mating pipe area.

6. Gear operated requiring not more than 50 pounds (lbs) force at the rim of the hand wheel under all operating conditions.

7. Furnished with travel stops for the full open and closed positions and provided with intermediate position indication in 15 degree increments.

8. Rated for minimum 175 psi working pressure.

C. Swing Check Valves:
   1. Cast iron in accordance with ASTM A-126 Class B, with a 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. The inside of the valve:
   a. Rubber lined such that internally the valve has no exposed metal surfaces.

5. Have a positive non-slip backflow device, for the purpose of backflushing the pumps.

6. Have a phenolic primer red oxide exterior coating.

7. Swing check valve: APCO Model 120 or approved equal

D. Ball Valves:
   1. Two inches and smaller for drain service:
a. Cast iron body, ASTM A 126, Class B
b. Have threaded end connections.

2. Cast iron ASTM A 126 Class B or ductile iron ASTM A 536 ball.
3. Seats: Cast Monel, ASTM B 127 or BUNA-N rubber
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. Automatic Ball Drain:
   1. Automatic Drain Valves: 1/2 inch cast brass, angle design.
   2. Designed to seal automatically at pressures above 20 ft of water column.
   3. Potter Roemer Model 5983 or approved equal.

2.03 HANGERS AND SUPPORTS

A. Conform to MSS SP-58, MSS SP-69, Fed. Spec. WW-H-171E, ANSI B31.1, as indicated on the Contract Drawings and as specified in Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment, unless indicated otherwise.

B. Provide all stainless steel materials in the Wet Well areas and stainless steel or hot dip galvanized pipe hangers and supports in the Service Chambers.

2.04 PIPING APPURTENANCES

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.
   1. Above Grade:
      a. ASTM A53 Schedule 40 or Standard Weight, hot-dip galvanized steel pipe sleeves or cast in place with smooth inside surfaces.
      b. Sealant: Provide the required separation between the adjacent Class, Div. 2 Group Area.
   2. Below Grade (or one side in contact with dirt): Thermoplastic with integral seal ring.

C. Pipe to Wall and Pipe to Floor Penetration Closure:
   1. Seals: Modular mechanical type, consisting of interlocking synthetic rubber links shaped to continuously fill the annular space between the pipe and wall opening.
      a. Links: Loosely assembled with bolts to form a continuous rubber belt around the pipe with a pressure plate under each bolt head and nut.
2. After the seal assembly is positioned in the sleeve, tighten bolts to expand the rubber sealing elements and provide an absolutely watertight seal between the pipe and wall opening.

3. All steel parts: 316 stainless steel.

4. Manufacturer: Link Seal, Thunderline Corporation, or equal.

D. Miscellaneous Steel:

1. Pipe supports, hangers, anchors, sleeves, and associated steelwork:
   a. Hot dip galvanized in accordance with ASTM A 153, 2 ounces per square foot minimum.
   b. Configured as indicated on Contract Drawings.

E. Expansion Shields:

1. Fed. Spec. FF-S-325

2. Of group, type, class, and style best suited for the purpose

3. Recessed not less than 2-1/2 inches into concrete or masonry, unless indicated otherwise.

4. Do not use devices of Groups IV, V, VI, and VII in sizes greater than 1/2 inch unless indicated.

5. Stainless steel.

2.05 PIPING IDENTIFICATION:

A. Provide permanent flexible non-fading markers conforming to ANSI A13.1 in color, letter size and label size.

B. Permanent washable, chemical, and environmental resistant.

C. Provide non-metallic fasteners with each marker.

D. Label designation and coloring as indicated in Sound Transit Standards.

E. Indicate flow direction with arrows adjacent to labels.

F. Spacing no greater than 10 feet.

G. Piping Identification:

1. Fluid: Storm water

2. Background: Green

3. Lettering: White

H. Manufacturer/Model: Seton No. STR or approved equal.
2.06 SUMP PIT APPURTEANCES

A. Aluminum Angle Frame Sump Access Hatch:

1. Performance Requirements: Provide 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" 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" 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" 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 (Access Doors At Pump Locations Only): 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.

3. Finish: ASTM A123 hot dipped galvanized for frame and 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. Safety Extensions: Dual retractable aluminum posts on each side of ladder rung. Posts shall extend 54-inches above top most ladder rung in raised position.

5. Attachments: Anchor bolts as indicated on Contract Drawings. See Section 21 05 00, Common Work Results For Fire Suppression, for anchor bolt specification.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Piping

1. Install in accordance with the general requirements for installation of pipelines and with the applicable requirements of ANSI/ASME B31.1 and AWWA C600 each as applicable, except as otherwise specified or indicated on the Contract Drawings. 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. Employ the Contractors Quality Control representative before and after installation to inspect pipe, fittings, valves, and accessories. Reject those found defective.

2. Clean pipe and fittings to free from fins and burrs. Before placing in position, clean pipe, fittings, valves, and accessories be maintained in a clean condition.

3. Provided equipment for lowering sections of pipe into position. Do not, under no circumstances, drop or dump pipe, fittings, valves, or any other water line material into the work area.

4. Cut pipe accurately to measurements established at the site and work into place without springing or forcing. Replace any pipe or fitting that does not allow sufficient space for installation of jointing material with one of acceptable dimensions.

5. Provide anchors and support as indicated.

6. Keep the wet well free of water until force main has been connected and pipe through floor closures have been completed.

7. Seal open ends of pipe temporarily with plastic or wood end caps or bulkheads.

8. Repair all erection damage to pipe lining in accordance with AWWA C104.

9. Repair buried pipe coatings and covering of field joints with a two-coat epoxy coating conforming to Steel Structures Painting Council Paint No. 16. Apply to a minimum dry film thickness of 20 mils.
10. Brush bare steel surface to remove all mill scale prior to the application of the protective coating. Follow manufacturer's instructions for surface preparation.

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 all flanged pipe or fitting whose dimensions do not allow the making 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. Install pipe with end separation between straight pipe lengths of that rated for flexible radius cut grooves to allow for expansion and contraction of piping systems.

E. Valves

1. Install valves in accordance with AWWA C600. Install all valves in locations indicated on Contract Drawings and in accordance with manufacturer's written instructions.

F. Hanger and Support

1. Support piping at points indicated on Contract Drawings with type of hanger indicated and elsewhere as required by Section 22 05 29, Hangers and Supports for Plumbing Piping and Equipment, and the referenced standards.

2. Vertical Piping: Supported at floor and at not more than 10-foot intervals.

3. Horizontal Piping: Supported as indicated on Contract Drawings. Support the 3-inch diameter cast iron drain line and all other lines smaller than 3 inch 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 assure 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 indicated on Contract Drawings and in any location 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 on Contract Drawings. If anchors are needed, but not indicated on Contract Drawings, 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. Inserts: stainless steel unless indicated or specified otherwise. Slotted inserts: of types required to engage with anchors. Anchors and anchor bolts in walls: stainless steel with nuts of a heavy duty corrosion resistant alloy. 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.

3.02 FIELD QUALITY CONTROL

A. Hydrostatic Test

1. Pressure Piping:
   a. Meet the requirements of AWWA Standard C600
   b. Tested no less than two days after piping is complete
   c. Tested no less than five days after concrete thrust blocks have been placed

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.
   b. Test plugs or caps or blind flanges: Capable of withstanding an internal pressure of 100 psi.
   c. Remove all instruments or other items that may be damaged by the test pressure.
   d. 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.
   e. Apply 30 psi for eight consecutive hours to allow the cement lining to absorb moisture. Add water as required to make up loss.
   f. Test piping at a static pressure of 70 psi over a period of not less than four consecutive hours.
   g. Considered the test successful when the pressure drop over the test period is five psi or less.
   h. Repair all leaks and repeat the test until the pressure drop over the test period is five pounds per square inch or less.
i. Remove all test equipment and plug all test holes at completion of test. Replace plugs watertight.

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CONTRACT SPECIFICATIONS

SECTION 22 14 13

FACILITY STORM DRAINAGE PIPING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following storm drainage piping inside the building.

1. Pipe, tube, and fittings.
2. Special pipe fittings.

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 22 05 00, Common Work Results for Plumbing.
2. Section 22 05 29, Hanger and Supports for Plumbing Piping and Equipment.
3. Section 22 05 48, Vibration and Seismic Controls for Plumbing Piping and Equipment.
4. Section 22 14 23, Storm Drainage Piping Specialties.
5. Section 33 40 00, Storm Drainage Utilities.

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)
   b. ASTM C564 Standard Specification for Rubber Gaskets for Cast Iron Soil Pipe and Fittings
   d. ASTM D2321 Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications
2. American Society of Mechanical Engineers (ASME)
   a. ASME B16.45 Cast Iron Fittings for Solvent Drainage Systems
3. Cast Iron Soil Pipe Institute (CISPI)
4. Manufacturers Standardization Society (MSS)
   a. MSS SP-69 Pipe Hangers and Supports – Selection and Application

1.03 PERFORMANCE REQUIREMENTS

A. Components and installation shall be capable of withstanding the following minimum working pressure, unless otherwise indicated:
   1. Storm Drainage Piping: 10-foot head of water.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Field quality-control inspection and test reports.

1.05 QUALITY ASSURANCE

A. Piping materials shall bear label, stamp, or other markings of an Independent Testing Laboratory.

PART 2 - PRODUCTS

2.01 PIPING MATERIALS

A. Hubless Cast-Iron Pipe and Fittings: ASTM A 888 or CISPI 301.
   1. Solvent Stack Fittings: ASME B16.45 or ASSE 1043, hubless, cast-iron aerator and deaerator drainage fittings.
   2. Shielded Couplings: ASTM C 1277 assembly of metal shield or housing, corrosion-resistant fasteners, and rubber sleeve with integral, center pipe stop.
      a. Standard, Shielded, Stainless-Steel Couplings: CISPI 310, with stainless-steel corrugated shield; stainless-steel bands and tightening devices; and ASTM C 564, rubber sleeve.

B. Solid-Wall PVC Pipe: ASTM D 2665, solid-wall drain, waste, and vent.
1. PVC Socket Fittings: ASTM D 2665, made to ASTM D 3311, drain, waste, and vent patterns.

**PART 3 - EXECUTION**

**3.01 PIPING APPLICATIONS**

A. Special pipe fittings with pressure ratings at least equal to piping pressure ratings may be used in applications below, unless otherwise indicated.

B. Aboveground storm drainage piping NPS 6 and smaller shall be the following:
   1. Hubless cast-iron soil pipe and fittings; heavy-duty shielded, stainless-steel couplings; and hubless-coupling joints.

C. Underground storm drainage piping NPS 6 and smaller shall be the following:
   1. Solid-wall PVC pipe, PVC socket fittings, and solvent-cemented joints.

**3.02 PIPING INSTALLATION**

A. Storm sewer and drainage piping outside the building are specified in Section 33 40 00, Storm Drainage Utilities.

B. Basic piping installation requirements are specified in Section 22 05 00, Common Work Results for Plumbing.

C. Install cleanouts at grade and extend to where building storm drains connect to building storm sewers. Cleanouts are specified in Section 22 14 23, Storm Drainage Piping Specialties.

D. Install cast-iron sleeve with water stop and mechanical sleeve seal at each service pipe penetration through foundation wall. Select number of interlocking rubber links required to make installation watertight. Sleeves and mechanical sleeve seals are specified in Section 22 05 00, Common Work Results for Plumbing.

E. Install cast-iron soil piping according to CISPI's "Cast Iron Soil Pipe and Fittings Handbook," Chapter IV, "Installation of Cast Iron Soil Pipe and Fittings."

F. Make changes in direction for storm piping using appropriate branches, bends, and long-sweep bends. Do not change direction of flow more than 90 degrees. Use proper size of standard increasers and reducers if pipes of different sizes are connected. Reducing size of drainage piping in direction of flow is prohibited.

G. Lay buried building drain piping beginning at low point of each system. Install true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets according to manufacturer's written instructions for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.

H. Install storm drainage piping at the following minimum slopes, unless otherwise indicated:
   1. Building Storm Drain: 1 percent downward in direction of flow for piping NPS 3 and smaller; 1 percent downward in direction of flow for piping NPS 4 and larger.
   2. Horizontal Storm-Drainage Piping: 2 percent downward in direction of flow.
I. Sleeves are not required for cast-iron soil piping passing through concrete slabs-on-grade if slab is without membrane waterproofing.

J. Install PVC storm drainage piping according to ASTM D 2665.

K. Install underground PVC storm drainage piping according to ASTM D 2321.

L. Do not enclose, cover, or put piping into operation until it is inspected and approved by authorities having jurisdiction.

3.03 JOINT CONSTRUCTION

A. Basic piping joint construction requirements are specified in Section 22 05 00, Common Work Results for Plumbing.

B. PVC Nonpressure Piping Joints: Join piping according to ASTM D 2665.

3.04 VALVE INSTALLATION

A. Backwater Valves: Install backwater valves in piping subject to backflow.

1. Horizontal piping: Horizontal backwater valves. Use normally closed type, unless otherwise indicated.

2. Install backwater valves in accessible locations.

3. Backwater valve are specified in Section 22 14 23, Storm Drainage Piping Specialties.

3.05 HANGER AND SUPPORT INSTALLATION

A. Seismic-restraint devices are specified in Section 22 05 48, Vibration and Seismic Controls for Plumbing Piping and Equipment.

B. Pipe hangers and supports are specified in Section 22 05 29, Hanger and Supports for Plumbing Piping and Equipment. Install the following:

1. Vertical piping: MSS Type 8 or Type 42, clamps.

2. Individual, Straight, Horizontal Piping Runs: According to the following:
   a. 100 Feet and Less: MSS Type 1, adjustable, steel clevis hangers.
   b. Longer Than 100 Feet: MSS Type 43, adjustable roller hangers.
   c. Longer Than 100 Feet, if Indicated: MSS Type 49, spring cushion rolls.

3. Multiple, Straight, Horizontal Piping Runs 100 Feet or Longer: MSS Type 44, pipe rolls. Support pipe rolls on trapeze.

4. Base of Vertical Piping: MSS Type 52, spring hangers.

C. Install supports according to Section 22 05 29, Hanger and Supports for Plumbing Piping and Equipment.

D. Support vertical piping and tubing at base and at each floor.
E. Rod diameter may be reduced one size for double-rod hangers, with 3/8-inch minimum rods.

F. Install hangers for cast-iron soil piping with the following maximum horizontal spacing and minimum rod diameters:
   1. NPS 1-1/2 and NPS 2: 60 inches with 3/8-inch rod.
   2. NPS 3: 60 inches with 1/2-inch rod.
   3. NPS 4 and NPS 5: 60 inches with 5/8-inch rod.
   4. NPS 6: 60 inches with 3/4-inch rod.
   5. Spacing for 10-foot lengths may be increased to 10 feet. Spacing for fittings is limited to 60 inches.

G. Install supports for vertical cast-iron soil piping every 15 feet.

H. Install hangers for steel piping with the following maximum horizontal spacing and minimum rod diameters:
   1. NPS 1-1/4: 84 inches with 3/8-inch rod.
   2. NPS 1-1/2: 108 inches with 3/8-inch rod.
   3. NPS 2: 10 feet with 3/8-inch rod.
   4. NPS 2-1/2: 11 feet with 1/2-inch rod.
   5. NPS 3: 12 feet with 1/2-inch rod.
   6. NPS 4 and NPS 5: 12 feet with 5/8-inch rod.
   7. NPS 6: 12 feet with 3/4-inch rod.

I. Install supports for vertical steel piping every 15 feet.

J. Install hangers for copper tubing with the following maximum horizontal spacing and minimum rod diameters:
   1. NPS 1-1/4: 72 inches with 3/8-inch rod.
   2. NPS 1-1/2 and NPS 2: 96 inches with 3/8-inch rod.
   3. NPS 2-1/2: 108 inches with 1/2-inch rod.
   4. NPS 3 to NPS 5: 10 feet with 1/2-inch rod.
   5. NPS 6: 10 feet with 5/8-inch rod.

K. Install supports for vertical copper tubing every 10 feet.

L. Install hangers for PVC piping with the following maximum horizontal spacing and minimum rod diameters:
   1. NPS 1-1/2 and NPS 2: 48 inches with 3/8-inch rod.
   2. NPS 3: 48 inches with 1/2-inch rod.
3. NPS 4 and NPS 5: 48 inches with 5/8-inch rod.

4. NPS 6: 48 inches with 3/4-inch rod.

M. Install supports for vertical PVC piping every 48 inches.

N. Support piping and tubing not listed above according to MSS SP-69 and manufacturer’s written instructions.

3.06 CONNECTIONS

A. Connect interior storm drainage piping to exterior storm drainage piping. Use transition fitting to join dissimilar piping materials.

B. Connect storm drainage piping to roof drains and storm drainage specialties.

3.07 FIELD QUALITY CONTROL

A. During installation, notify Resident Engineer and the Seattle Utility code authority at least 24 hours before inspection must be made. Perform tests specified below in presence of authorities having jurisdiction.

1. Roughing-in Inspection: Arrange for inspection of piping before concealing or closing-in after roughing-in.

2. Final Inspection: Arrange for final inspection by Resident Engineer and the Seattle Utility code authorities having jurisdiction to observe tests specified below and to ensure compliance with requirements.

B. Reinspection: If Resident Engineer and the Seattle Utility code authorities having jurisdiction find that piping will not pass test or inspection, make required corrections and arrange for reinspection.

C. Reports: Prepare inspection reports and have them signed by Resident Engineer and the Seattle Utility code authorities having jurisdiction.

D. Test storm drainage piping according to procedures of Resident Engineer and the Seattle Utility code authorities having jurisdiction.

3.08 CLEANING

A. Clean interior of piping. Remove dirt and debris as work progresses.

B. Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.

C. Place plugs in ends of uncompleted piping at end of day and when work stops.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following storm drainage piping specialties:

1. Backwater valves.
2. Cleanouts.
3. Roof drains.
4. Miscellaneous storm drainage piping specialties.

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 22 05 00, Common Work Results for Plumbing.

1.02 REFERENCES

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

1. American Society of Mechanical Engineers (ASME)
   a. ASME A112.14.1 Backwater Valves
   b. ASME A112.21.2M Roof Drains
   c. ASME A112.36.2M Cleanouts

   a. ASTM A74 Standard Specification for Cast-Iron Soil Pipe and Fittings

3. 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

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each type of product indicated.

1.04 QUALITY ASSURANCE

A. Drainage piping specialties shall bear label, stamp, or other markings of an Independent Testing Laboratory.

PART 2 - PRODUCTS

2.01 BACKWATER VALVES

A. Horizontal, Cast-Iron Backwater Valves:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. MIFAB, Inc.
   d. Tyler Pipe; Wade Div.
   e. Watts Drainage Products Inc.
   f. Zurn Plumbing Products Group; Specification Drainage Operation.


3. Size: Same as connected piping.


5. Cover: Cast iron with bolted or threaded access check valve.


7. Type Check Valve: Removable, bronze, swing check, factory assembled or field modified to hang closed.

8. Extension: ASTM A 74, Service class; full-size, cast-iron, soil-pipe extension to field-installed cleanout at floor; replaces backwater valve cover.

B. Drain-Outlet Backwater Valves:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   c. Watts Drainage Products Inc.
   d. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Size: Same as floor drain outlet.
3. Body: Cast iron or bronze made for vertical installation in bottom outlet of floor drain.
4. Check Valve: Removable ball float.
5. Inlet: Threaded.
6. Outlet: Threaded or spigot.

2.02 CLEANOUTS

A. Exposed Cast-Iron Cleanouts:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. MIFAB, Inc.
   d. Tyler Pipe; Wade Div.
   e. Watts Drainage Products Inc.
   f. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.36.2M for cast iron for cleanout test tee.
3. Size: Same as connected drainage piping
4. Body Material: Hubless, cast-iron soil pipe test tee as required to match connected piping.
5. Closure: Countersunk or raised-head, cast-iron plug.
6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.

B. Cast-Iron Floor Cleanouts:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. Oatey.
   c. Sioux Chief Manufacturing Company, Inc.
   e. Tyler Pipe; Wade Div.
f. Watts Drainage Products Inc.
g. Zurn Plumbing Products Group; Light Commercial Operation.
h. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.36.2M for heavy-duty, adjustable housing cleanout.

3. Size: Same as connected branch.

4. Type: Heavy-duty, adjustable housing.

5. Body or Ferrule: Cast iron.


7. Outlet Connection: Threaded.

8. Closure: Cast-iron plug.

9. Adjustable Housing Material: Cast iron with threads.


11. Frame and Cover Shape: Square.

12. Top Loading Classification: Extra Heavy-Duty.

13. Riser: ASTM A 74, Extra-Heavy class, cast-iron drainage pipe fitting and riser to cleanout.

C. Cast-Iron Wall Cleanouts:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:


   b. MIFAB, Inc.


   d. Tyler Pipe; Wade Div.

   e. Watts Drainage Products Inc.

   f. Zurn Plumbing Products Group; Specification Drainage Operation.

2. Standard: ASME A112.36.2M. Include wall access.

3. Size: Same as connected drainage piping.

4. Body: Hubless, cast-iron soil pipe test tee as required to match connected piping.

5. Closure: Countersunk or raised-head, drilled-and-threaded cast-iron plug.
6. Closure Plug Size: Same as or not more than one size smaller than cleanout size.

2.03 ROOF DRAINS
A. Cast-Iron Roof Drains:
1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. Marathon Roofing Products.
   c. MIFAB, Inc.
   d. Portals Plus, Inc.
   e. Prier Products, Inc.
   g. Tyler Pipe; Wade Div.
   h. Watts Drainage Products Inc.
   i. Zurn Plumbing Products Group; Light Commercial Operation.
   j. Zurn Plumbing Products Group; Specification Drainage Operation.
2. Standard: ASME A112.21.2M.
5. Dimensions of Body: scheduled
6. Combination Flashing Ring and Gravel Stop: Required.
8. Outlet: Bottom.
11. Underdeck Clamp: Required.

2.04 MISCELLANEOUS STORM DRAINAGE PIPING SPECIALTIES
A. Conductor Nozzles:
1. Description: Bronze body with threaded inlet and bronze wall flange with mounting holes.

2. Size: Same as connected conductor.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Refer to Section 22 05 00, Common Work Results for Plumbing, for piping joining materials, joint construction, and basic installation requirements.

B. Install cleanouts in aboveground piping and building drain piping according to the following, unless otherwise indicated:

1. Size same as drainage piping up to NPS 4. Use NPS 4 for larger drainage piping unless larger cleanout is indicated.

2. Locate at each change in direction of piping greater than 45 degrees.

3. Locate at minimum intervals of 50 feet for piping NPS 4 and smaller and 100 feet for larger piping.

4. Locate at base of each vertical soil and waste stack.

C. For floor cleanouts for piping below floors, install cleanout deck plates with top flush with finished floor.

D. For cleanouts located in concealed piping, install cleanout wall access covers, of types indicated, with frame and cover flush with finished wall.

E. Install roof drains at low points of roof areas according to roof membrane manufacturer's written installation instructions. Roof materials are specified in Division 07, Thermal and Moisture Protection.

1. Install roof-drain flashing collar or flange so that there will be no leakage between drain and adjoining roofing. Maintain integrity of waterproof membranes where penetrated.

2. Position roof drains for easy access and maintenance.

F. Install sleeve flashing device with each riser and stack passing through floors with waterproof membrane.

G. Install conductor nozzles at exposed bottom of conductors where they spill onto grade.

H. Install escutcheons at wall, floor, and ceiling penetrations in exposed finished locations and within cabinets and millwork. Use deep-pattern escutcheons if required to conceal protruding pipe fittings.

3.02 CONNECTIONS

A. Piping installation requirements are specified in other Division 22, Plumbing, Sections. Contract Drawings indicate general arrangement of piping, fittings, and specialties.
3.03 FLASHING INSTALLATION

A. Fabricate flashing from single piece unless large pans, sumps, or other drainage shapes are required. Join flashing according to the following if required:

1. Lead Sheets: Burn joints of lead sheets 6.0-lb/sq. ft., 0.0938-inch thickness or thicker. Solder joints of lead sheets 4.0-lb/sq. ft., 0.0625-inch thickness or thinner.

B. Install sheet flashing on pipes, sleeves, and specialties passing through or embedded in floors and roofs with waterproof membrane.

1. Pipe Flashing: Sleeve type, matching pipe size, with minimum length of 10 inches, and skirt or flange extending at least 8 inches around pipe.

2. Sleeve Flashing: Flat sheet, with skirt or flange extending at least 8 inches around sleeve.

3. Embedded Specialty Flashing: Flat sheet, with skirt or flange extending at least 8 inches around specialty.

C. Set flashing on floors and roofs in solid coating of bituminous cement.

D. Secure flashing into sleeve and specialty clamping ring or device.

3.04 PROTECTION

A. Protect drains during remainder of construction period to avoid clogging with dirt or debris and to prevent damage from traffic or construction work.

B. Place plugs in ends of uncompleted piping at end of each day or when work stops.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing track drainage pumps, sanitary sewerage pumps, and packaged wastewater submersible pumps, and motors at the following locations:

1. Tunnel track drainage pump station at Cross Passage No. 18.
2. Track drainage pump station at University of Washington Station Pump Room N5-5P25.
3. Sanitary sewerage pump station at University of Washington Station Janitor Room N5-5P12.
4. Elevator pit sumps, escalator pit sumps, low-point pit sumps where indicated on the drawings.

B. Track Drainage Pump Stations: Furnish and install submersible, non-clog type pumps and motors with appurtenances necessary to complete the work shown or specified herein. Obtain all pumps from one manufacturer. Pumps and pump equipment shall be warranted by manufacturer for a minimum of five years. In addition, ensure all components of the pumping units including pumps, motors, lifting chains, submersible power cable, guide rails, and discharge elbow are furnished by the same manufacturer. In addition, specific pump station requirements are provided below:

a. Pump Station at Cross Passage No. 18: The existing level controls and PLC have been installed prior to this work under a separate contract. Remove and install new level transmitter and float switches. Employ pump manufacturer to test these components in the field to perform the sequence of operation specified herein and deliver a fully functional operating system.

C. Sanitary Sewerage Pump Station: Furnish and install submersible, grinder type pumps and motors with appurtenances necessary to complete the work shown or specified herein. Obtain all pumps from one manufacturer. Pumps and pump equipment shall be warranted by manufacturer for a minimum of five years. In addition, ensure all components of the pumping units including pumps, motors, lifting chains, submersible power cable, guide rails, and discharge elbow are furnished by the same supplier.

D. Elevator Pit Sumps, Escalator Pit Sumps, and Low-Point Pit Sumps: Furnish and install packaged submersible wastewater sump pumps, automatic float switch, with appurtenances necessary to complete the work shown or specified herein. Obtain all pumps and appurtenances from one manufacturer. Pump and pump equipment shall be warranted by manufacturer for a minimum of five years.
1. At elevator and escalator pit sumps, provide additional oil detection control system to detect floating oil and prevent pump operation.

E. 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 22 14 01, Drainage System for Structures.
2. Section 26 05 00, Common Work Results for Electrical
3. Section 26 05 25, Wire and Cable.
4. Section 26 05 26, Grounding and Bonding for Electrical Systems
5. Section 26 05 33, Raceway and Boxes for Electrical Systems
6. Section 26 05 53, Identification for Electrical Systems
7. Section 26 08 00, Commissioning of Electrical Systems
8. Section 26 29 13, Enclosed Controllers.
9. 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 International (ASTM)
2. Insulated Cable Engineers Association (ICEA)
3. National Electric Code (NEC)
4. National Electrical Manufacturers Association (NEMA)
5. Hydraulic Institute Standards
   a. ANSI/HI 9.8 Centrifugal and Vertical Pump Intake Design
   b. ANSI/HI 11.6 Submersible Pump Tests
6. National Electrical Manufacturers Association (NEMA)
   a. NEMA B Application and Installation Guidelines for Nonmetallic-Sheathed Cables
7. Submersible Wastewater Pump Association
8. Underwriters Laboratories
   a. UL 778 Motor-Operated Water Pumps
1.03 DEFINITIONS

A. BMS: Building Management System
B. PLC: Programmable Logic Controller
C. FCS: Field Control System (FCS)
D. FM: Factory Mutual
E. MCC: Motor Control Center
F. NB: Northbound
G. SB: Southbound

1.04 PUMP CONTROL SYSTEM DESCRIPTION

A. University of Washington Track Drainage Pump Station: Pump Control System and Sequence of Operation:

1. During normal operations: Sump pumps shall be ready in the automatic mode to start automatically if the water level is sensed by the level sensor to be above the set point where pump needs to start and shut off when the water level goes below the set level where pump needs to stop.

2. Continuous sump level shall be sensed by a locally mounted level sensor and associated level transducer.

3. When an initial increasing liquid level (programmable BMS set point) is sensed in the sump, the small sump pump shall start and run until the level drops below a separately programmed BMS set point.

4. If the level is sensed to increase above a second separately programmed set point, one of the two large pumps shall start and run until the level decreases below a programmed set point. The large pump selected for operation shall be alternated by the BMS with each operating cycle.

5. If the liquid level is sensed to rise above a third, separately programmable set point, the second large sump pump shall turn on and run until the level decreases to a programmed level set point.

6. Every third operating cycle, (detection of initial level), operate one of the larger pumps in lieu of the smaller pump, as described in Article 1.04.A.2 herein.

7. Actuated Drain Valve Operation: After an operating cycle and all pumps have shut off, and a subsequent five minute timed period (adjustable set point), the drain valve shall be energized open for a timed period. At the end of the timed period the drain valve shall close. When any pump starts at any time, the drain valve shall close. The initial timed period at each pump station shall be as follows:
   a. University of Washington Pump Station: 5 minutes

8. A float switch assembly shall indicate a low-level cutoff level and a high level alarm signal. If the sump level falls to the low level cutoff point, all pumps shall be unconditionally shut off and a pump controller alarm output will result in a...
common alarm condition being annunciated at the Operations Control Center via the BMS.

9. The sump pump internal thermal switches and float leakage sensor (FLS) shall indicate and alarm signal.

10. Sump Pump Control Panel: Provide local indication of pump status and sump level.

B. Tunnel Track Drainage Pump Station at Cross Passage No. 18: Pump Control System and Sequence of Operation:

1. During normal operations: Sump pumps shall be ready in the automatic mode to start automatically if the water level is sensed by the level sensor to be above the set point where pump needs to start and shut off when the water level goes below the set level where pump needs to stop.

2. Continuous sump level shall be sensed by a locally mounted level transducer.

3. When an initial increasing liquid level (programmable BMS set point) is sensed in the sump, the small sump pump shall start and run until the level drops below a separately programmed BMS set point.

4. If the level is sensed to increase above a second separately programmed set point, one of the two large pumps shall start and run until the level decreases below a programmed set point. The large pump selected for operation shall be alternated by the BMS with each operating cycle.

5. If the liquid level is sensed to rise above a third, separately programmable set point, the second large sump pump shall turn on and run until the level decreases to a programmed level set point.

6. Every third operating cycle, (detection of initial level), operate one of the larger pumps in lieu of the smaller pump, as described in Article 1.04.A.2 herein.

7. Actuated Drain Valve Operation: After an operating cycle and all pumps have shut off, and a subsequent five minute timed period (adjustable set point), the drain valve shall be energized open for a timed period. At the end of the timed period the drain valve shall close. When any pump starts at any time, the drain valve shall close. The initial timed period at each pump station shall be as follows:

   a. Cross Passage No. 18 Pump Station: 5 Minutes

8. A float switch assembly shall indicate a low-level cutoff level and a high level alarm signal. A pump controller output will result in a common alarm condition being annunciated at the Operations Control Center via the existing PSST control system. If the sump level falls to the low level cutoff point, all pumps shall be unconditionally shut off and a pump controller alarm output will result in a common alarm condition being annunciated at the Operations Control Center via the BMS.

9. The sump pump internal thermal switches and float leakage sensor (FLS) shall indicate and alarm signal. A thermal overload or seal leakage condition will result in a common alarm condition being annunciated at the Operations Control Center via the existing PSST Control System.
10. Sump Pump PLC Control Panel: Provide local indication of pump status and sump level, as well as remote access to all sump control PLC programming parameters via fiber optic communication link (fiber provided by separate contract) to the existing PSST control system.

11. Sump Control PLC System: Linked to the existing PSST control system. A loss of communication with the existing PSST Control system shall not cause a failure of the PLC to properly respond to sump liquid level increases.

12. Program and test the PLC in the field to assure it performs all control and communications functions needed for controlling all three pumps at each NB and SB pump station.

C. Sanitary Sewerage Pump Station at University of Washington: Pump Control System and Sequence of Operation:

1. During normal operations: Sump pumps shall be ready in the automatic mode to start automatically if the water level is sensed by the level sensor to be above the set point where pump needs to start and shut off when the water level goes below the set level where pump needs to stop.

2. Continuous sump level shall be sensed by a locally mounted level transducer.

3. When an initial increasing liquid level (programmable BMS set point) is sensed in the sump, the first sump pump shall start and run until the level drops below a separately programmed BMS set point.

4. If the level is sensed to increase above a second separately programmed set point, the second pump shall start and run until the level decreases below a programmed set point. The first pump selected for operation shall be alternated by the BMS with each operating cycle.

5. Actuated Drain Valve Operation: After an operating cycle and all pumps have shut off, and a subsequent five minute timed period (adjustable set point), the drain valve shall be energized open for a timed period. At the end of the timed period the drain valve shall close. When any pump starts at any time, the drain valve shall close. The initial timed period at each pump station shall be as follows:

a. Capitol Hill Station Pump Station: 5 minutes

6. A float switch assembly shall indicate a low-level cutoff level and a high level alarm signal. If the sump level falls to the low level cutoff point, all pumps shall be unconditionally shut off.

7. The sump pump internal thermal switches and float leakage sensor (FLS) shall indicate and alarm signal.

8. The sump pump control panel: Provide local indication of pump status and sump level.

1.05 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Submit the following:

1. Certified copies of reports of factory tests specified in this Section and/or required by the referenced standards.

2. Shop drawings with performance data and physical characteristics.

3. Pump/Motor performance charts showing curves for torque, current, power factor, input/output KW and efficiency.

4. Manufacturer's installation instructions.

5. Manufacturer's operation and maintenance material and manuals, in accordance with Section 33 01 00, Operation and Maintenance of Utilities.

6. Provide technical details for control and power wiring of sufficient length for field installation inside the pump control enclosure. These wires come as pre-installed at pump motors and included in shipping package of the equipment specified in this Section.

1.06 PROJECT COORDINATION

A. See Section 01 31 13, Project Coordination and Section 22 05 00, Common Work Results for Plumbing, for requirements.

B. Temporary Pumps: Coordinate the work of this section with the temporary pumps required by Section 01 50 00, Temporary Facilities and Controls.

1.07 DELIVERY, STORAGE, AND HANDLING

A. Promptly remove damaged products from the job site. Replace damaged products with undamaged products

B. Thoroughly clean all equipment, components, and subassemblies of all water, sand, grit, weld splatter, grease, oil, and other foreign materials before preparation for shipment.

C. Protect all machined surfaces against physical damage and exposure to the elements during shipment, handling, storage, and installation.

D. Pack pumps to provide ample protection from damage during shipment, handling, and storage.

1. Cap and seal all openings.

2. Protect control and power wiring from insulation damage.

PART 2 - PRODUCTS

2.01 SUBMERSIBLE TRACK DRAINAGE PUMPS

A. General Requirements:

1. Mating cast iron discharge connection of size indicated.

2. 30 feet of stainless steel lifting cable or chain as required. Employ a lifting system with a working strength of 50 percent greater than the pump unit weight.
3. Capable of delivering the gallons per minute (gpm) at the static and total dynamic head (TDH) as scheduled on the Contract Drawings.

4. Pumps shall have continuously rising head curve to shutoff.

5. Meet the applicable requirements of the Hydraulic Institute Standards

6. Provide the power/instrument cable in lengths suited to the individual installations, but in no case less than 40 feet long.

B. Pump Design:

1. Automatically and firmly connected to the discharge connection, guided by no less than two guide bars extending from a bracket at the access opening to the discharge connection.

2. Sealed to the discharge connection by means of a machined metal to metal watertight contact. Do not allow any portion of the pump to bear directly on the sump floor.

C. Pump Construction:

1. ASTM A48, class 35B, gray cast iron, with smooth surfaces devoid of blow holes and other irregularities

2. Exposed Nuts and Bolts: AISI type 304 stainless steel

3. Metal Surfaces Coming into Contact with Storm Water (other than stainless steel or brass): Factory applied spray coating of acrylic dispersion zinc phosphate primer with a polyester resin paint finish on the exterior of the pump.

4. The pump system including the pump, motor and power cable shall be approved for use in areas classified as hazardous locations in accordance with the NEC Class I, Div. 2, Group C and D service as determined and approved by a U.S. nationally recognized Independent Testing Laboratory (U.L., FM).

D. Cooling System:

1. Non-Clog Pumps: Have integral motor cooling system conforming to the following description: A motor cooling jacket encircles the stator housing, providing for dissipation of motor heat regardless of the type of pump installation. An impeller, integral to the cooling system and driven by the pump shaft, provides the necessary circulation of the cooling liquid through the jacket. The cooling liquid passes about the stator housing in the closed loop system in turbulent flow providing for heat transfer. The cooling system has one fill port and one drain port integral to the cooling jacket. The cooling system shall provide for continuous pump operation in liquid temperatures up to 104 degrees F.

E. Cable Entry Seal:

1. Of a design that precludes specific torque requirements while ensuring a watertight and submersible seal.

2. Consists of a single cylindrical elastomer grommet, flanked by washers, all having a close tolerance fit against the cable outside diameter and the entry inside diameter and compressed by the body containing a strain relief function, separate
from the function of sealing the cable. This assembly design allows for easy changing of the cable using the same entry seal when necessary.

3. Cable entry junction chamber and motor: separated by a terminal board which isolates the interior of the motor from foreign material gaining access through the pump top.

4. Attached to a 40 foot minimum long cable sized according to NEC and ICEA standards and an outer cable jacket made of oil resistant chloroprene rubber.

5. Use of epoxies, silicones, or other secondary sealing systems is not acceptable.

F. Motor:

1. Induction type with a squirrel cage rotor, shell type design, housed in an air filled watertight chamber.

2. NEMA type B with Class H insulation.

3. Stator:
   a. With windings and leads that are insulated with moisture resistant Class H insulation rated for 356 degrees F.
   b. Insulated by the trickle impregnation method using Class H monomer-free polyester resin resulting in a winding fill factor of at least 95 percent.
   c. Heat-shrink fitted into the cast iron stator housing.
   d. Do not use bolts, pins or other fastening devices requiring penetration of the stator housing.

4. Designed for continuous duty handling storm water at 104 degrees F and capable of up to 15 evenly spaced starts per hour.

5. Preset thermal switches:
   a. Set to open at 260 degrees F.
   b. Embedded in the stator lead coils to monitor the temperature of each phase winding.
   c. Used in conjunction with and supplemental to external; motor overload protection.

6. Hermetically sealed junction chamber containing the terminal board from the motor by an elastomer O-ring seal.

7. Connection between the cable conductors and stator leads with threaded compression type; binding posts permanently affixed to the terminal board.

8. Designed and assembled by the same manufacturer as the pump.

9. Designed for continuous operation up to 104 degrees F ambient with a NEMA Class B maximum operating 176 degrees F temperature rise.
10. Combined service factor of 1.15 and a voltage tolerance of plus or minus 10 percent.

11. Suitable for installation in a Class 1, Division 2, and Group C and D classified area. Use associated cable suitable for installation in a Class 1, Division 1, and Group C and D classified area as well.

12. Nameplate motor horsepower: Non-overloading throughout the entire pump performance curve from shut-off to run-out.

13. Capable of continuous submergence under 65 foot depth of water.

G. Bearings:

1. Support rotating pump shaft on two bearings:
   a. Permanently grease lubricated

2. Upper bearing: Single roller type

3. Lower bearing: Two row angular contact type to compensate for axial thrust and radial forces.

H. Mechanical Seal:

1. On each pump: positively driven tandem mechanical shaft seal system including two seal sets, each having an independent spring:
   a. The lower, primary seal unit:
      1) Located between the pump and the lubricant chamber
      2) Contain one stationary and one positively driven rotating tungsten-carbide ring
   b. The upper, secondary seal unit:
      1) Located between the lubricant chamber and the motor housing
      2) Contain one stationary tungsten-carbide seal ring and one positively driven rotating tungsten-carbide seal ring.

2. All seal rings: made up of individual solid sintered rings.

3. Lubrication of the seals: From lubricant reservoir that hydrodynamically lubricates the lapped seal faces of the stationary and rotating tungsten carbide rings.

4. Seal interfaces: held in contact using its own spring system.

5. No seals which require maintenance or adjustment or depend on direction of rotation for sealing.

6. Spin-Out Protection:
   a. Designs in which seals and bearing housing are protected by seal wear protection.
b. Helical design that expels abrasive particles from the area around the
seal chamber.

7. Lubricant chamber to prevent overfilling and to provide for expansion. Locate
drain and inspection plug to allow easy access from the outside. Do not design
the seal system to rely upon the pumped media for lubrication.

I. Pump Shaft:
1. In the same unit as the motor shaft. Couplings are not acceptable. Use AISI type
431 stainless steel for the shaft.

J. Impeller:

1. Non-Clog Pumps:
   a. Gray cast iron, ASTM A48 class 35B, dynamically balanced, semi-open,
      multi-vane, back swept, screw-shaped, non-clog design.
   b. Leading edges:
      1) Mechanically self-cleaned automatically upon each rotation as
         they pass across a spiral groove located on the volute suction.
      2) Screw-shaped, hardened to Rc 45 and capable of handling
         solids, fibrous materials, heavy sludge and other matter normally
         found in transit tunnel wastewater.
   c. Inlet with a screw shaped to provide an inducing effect for the handling of
      up to 5 percent sludge and rag-laden wastewater.
   e. Locked to the shaft, held by an impeller bolt and coated with alkyd resin
      primer.

K. Volute:
   1. A48 Class 35B gray cast iron.
   2. Integral spiral shaped cast groove(s) at the suction.
   3. Effectively sealing against the multi-vane, semi-open impeller.
   4. Sharp spiral groove(s) which provide the shearing edge(s) across which each
      impeller vane leading edge crosses during its rotation in order to remain
      unobstructed.
   5. Adjustable clearance between the internal volute bottom and the impeller leading
      edges.

L. Protection:
   1. Thermal switches for each phase which are wired in series to open at 260
      degrees F
   2. Float type leakage sensor (FLS) to detect water in the seal leakage chamber.
3. Connect the thermal switches and FLS to a Control & Monitoring Unit provided by the pump manufacturer for mounting in the field inside the pump controller for input to BMS.

2.02 SUBMERSIBLE SEWAGE PUMPS

A. Submersible, Quick-Disconnect Grinder Pumps: Factory-assembled and -tested, duplex, single-stage, centrifugal, end-suction, submersible, direct-connected grinder pumps complying with UL 778 and with HI 1.1-1.2 and HI 1.3 for submersible sewage pumps and with SWPA's "Submersible Sewage Pumping Systems (SWPA) Handbook" for guide-rail supports.

B. Casing: Cast iron, with open inlet, legs (or guide-rail supports) that elevate pump to permit flow into impeller, and vertical discharge with companion flange for piping connection.

C. Impeller: Bronze or stainless steel; statically and dynamically balanced, with stainless-steel cutter, grinder, or slicer assembly and capable of handling solids; overhung, single suction, and keyed and secured to shaft.

D. Pump and Motor Shaft: Stainless steel, with factory-sealed, grease-lubricated ball bearings and double mechanical seals.

E. Motor: Hermetically sealed, capacitor-start type; with built-in overload protection; lifting eye or lug; and three-conductor, waterproof power cable of length required and with grounding plug and cable-sealing assembly for connection at pump.
   1. Motor Housing Fluid: Oil.

F. Guide-Rail Supports: Include the following for each sewage pump:
   1. Guide Rails: Vertical pipes or structural members, made of galvanized steel or other corrosion-resistant metal, attached to baseplate and basin sidewall or cover.
   2. Baseplate: Corrosion-resistant metal plate, attached to basin floor, supporting guide rails and stationary elbow.
   3. Pump Yoke: Motor-mounted or casing-mounted yokes or other attachments for aligning pump during connection of flanges.
   5. Stationary Elbow: Fixed discharge-elbow fitting with flange that mates to movable-elbow flange and support attached to baseplate.

G. Pump Discharge Piping; Refer to Section 22 14 10, Pumping Station Piping and Appurtenances.

H. Protection:
   1. Thermal switches for each phase which are wired in series to open at 260 degrees F
   2. Float type leakage sensor (FLS) to detect water in the seal leakage chamber.
3. Connect the thermal switches and FLS to a Control & Monitoring Unit provided by the pump manufacturer for mounting in the field inside the pump controller for input to BMS.

2.03 PACKAGED, SUBMERSIBLE WASTEWATER PUMP UNITS

A. Factory-assembled and -tested, single-stage, centrifugal, end-suction, automatic-operation, submersible effluent pump unit.

B. Pump Body and Impeller: Corrosion-resistant materials.

C. Pump Seals: Mechanical type.

D. Motor: Hermetically sealed, capacitor-start type, with built-in overload protection. Comply with requirements herein.

E. Power Cord: Three-conductor, waterproof cable of length required but not less than 72 inches (1830 mm) and with grounding plug and cable-sealing assembly for connection at pump.

F. Pump Controls: Pump manufacturers simplex pump control panel, NEMA 4X enclosure, circuit breaker, motor contactor, control transformer, level control flow switch and high level float switch, run light, high level alarm light and horn with silence switch, one remote monitoring contact.

G. Oil Detection Control System: Pump manufacturer’s controls to prevent pump operation when lighter-than-water oils are detected. Include NEMA 4X enclosure, stainless steel conductivity sensor probe, relays with sensitivity settings, alarm horn with alarm silencing switch, one remote monitoring contact.

H. Include all manufacturer’s inter-connecting power cables, sensor cables, control cables, probe cables, connecting plugs and receptacles. A minimum of 20 feet of cable shall be provided from the pump to the control panel.

2.04 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 negative 40 degrees F to 176 degrees F.

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).

2.05 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 VAC.
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.

2.06 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.
         a. Cable: Long enough to reach track drainage pump control panel without any splices.

PART 3 - EXECUTION

3.01 EXAMINATION
   A. Examine roughing-in of plumbing piping to verify actual locations of storm drainage piping connections before sump pump installation.
   B. Examine areas, surfaces and substrates, and roughing-in for conduit systems to receive VFCs for compliance with requirements, installation tolerances, and other conditions affecting performance.

3.02 INSTALLATION
   A. Coordinate installation of sump pump motors and controls with the requirements of Section 26 05 00 Common Work Results for Electrical Systems, 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 29 13, Enclosed Controllers.
   B. Sump Pump Installation:
      1. As indicated and according to manufacturer’s written instructions.
      2. Lubricate all moving parts as recommended by the manufacturer’s written instructions.
      3. Anchor each pump securely with minimum embedment in solid concrete as indicated.
      4. Make all connections tight.
5. Pumping units: Level and plumb to ensure the units are uniformly supported.

6. Test for ease of pump movement on slide rails before permanently securing discharge flange in place.

7. Test for leakage at pump discharge flange

C. Nameplate: For each storm water pump, located where it can be easily read.

D. Cleaning: Clean grease, oil, or all other debris from the exterior surfaces of the pumps and motors.

E. Control Installation:
   1. Coordinate with Instrumentation and Electrical regarding purchase, installation and adjustment of controls.
   2. Anchor each VFC assembly to steel-channel sills arranged and sized according to manufacturer's written instructions. Attach by bolting. Level and grout sills flush with mounting surface.
   3. Bundle, train, and support wiring in enclosures.

F. Level Sensors:
   1. Install float switches and level transducer in accordance with manufacturers installation instructions.
   2. Adjust level transmitter and float switches to actuate at levels indicated by temporary pump supplier.

G. Access Requirements: Coordinate with type and location of access hatches and lifting device to ensure that pumps can easily be removed and services.

H. Instruction: Arrange for manufacturer's service representatives to provide instruction in maintenance and operation activities.

I. The gravity drainage system is not included in the scope of this section and is described in Contract Specification Section 22 14 01, Drainage System for Structures.

J. Provide temporary power to test pump installation at no additional cost to Sound Transit.

3.03 CONNECTIONS

A. Conduit installation requirements are specified in other Division 26, Electrical, Sections. Drawings indicate general arrangement of conduit, fittings, and specialties.

B. Ground equipment according to Section 26 05 26, Grounding and Bonding for Electrical Systems.

3.04 FIELD QUALITY CONTROL

A. Cleaning
   1. After installation, thoroughly clean the wet well of all solids, dirt and other debris

B. Pump Tests
1. Provide and dispose all water required for the testing. Refer to Section 01 57 24, Temporary Site Water Discharge for testing water disposal requirements.

2. Use testing instruments calibrated by a qualified Independent Testing Laboratory in accordance with Section 01 45 00, Quality Control.

3. Each pump in accordance with the manufacturer's written instructions and as specified in Section 22 14 01, Drainage System for Structures.

4. Field test each pump to establish field head and overall efficiency. Take voltage, power and amperage measurements for each test and include in the test report.

5. Run each pump individually for at least 20 minutes. Allow pumps to cycle through their normal operating sequence by operating them in automatic mode through the level control system. Provide all water required for testing at no additional cost to Sound Transit.

6. Record pressure with permanently installed gauges and flows with portable measuring equipment. Field test for each size of pump, operating individually, by recording pressure and flow. The Flow rate may be measured by using portable measuring equipment or by noting the drop in the height of the water level in the sump during operation for a minimum period of time. The Resident Engineer will determine this minimum operation time period for calculating flow prior to the test. Record voltage, amps, power and power factor during all test modes of operation.

7. Adjust plug valve(s) to control flow rate if requested to do so by the Resident Engineer.

END OF SECTION
SECTION 22 33 00
ELECTRIC DOMESTIC WATER HEATERS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes the following:
   1. Commercial, storage electric water heaters.
   2. Water heater accessories.

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 22 05 00, Common Work Results for Plumbing.
   2. Section 22 05 19, Meters and Gages for Plumbing Piping.
   3. Section 22 11 19, Domestic Water Piping Specialties.
   4. Section 26 05 25, Wire and Cable.
   5. Section 26 05 26, Grounding and Bounding for Electrical Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASRAE)
      a. ASHRAE/ESNA 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings
      b. ASHRAE/ESNA 90.2 Energy-Efficient Design of Low-Rise Residential Buildings
   2. American Society of Mechanical Engineers (ASME)
      a. ASME B1.16.5 Pipe Flanges and Flanged Fittings
      b. ASME B1.16.24 Cast Copper Alloy Pipe Flanges and Flanged Fittings: Classes 150, 300, 600, 900, 1500 and 2500
      c. ASME B1.20.1 Pipe Threads, General Purpose (Inch)
      d. ASME PTC 25.3 Pressure Relief Devices
   3. American Society of Safety Engineers (ASSE)
a. ASSE 1003 Performance Requirements for Water Pressure Reducing Valves
b. ASSE 1005 Performance Requirements for Water Heater Drain Valves
c. ASSE 1010 Performance Requirements for Water Hammer Arresters

4. National Fire Protection Association (NFPA)

5. (NSF)
a. NSF 5 Water Heaters, Hot Water Supply Boilers and Heat Recovery Equipment
b. NSF 61 Drinking Water System Components – Health Effects

6. Underwriter Laboratories Inc. (UL)
a. UL 1453 Electric Booster and Commercial Storage Tank Water Heaters

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each type and size of water heater indicated. Include rated capacities, operating characteristics, furnished specialties, and accessories.
C. Shop Drawings: Diagram power, signal, and control wiring.
D. Operation and maintenance data.
E. Warranty.

1.04 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable to authorities having jurisdiction, and marked for intended use.
B. ASME Compliance: Where ASME-code construction is indicated, fabricate and label commercial water heater storage tanks to comply with ASME Boiler and Pressure Vessel Code: Section VIII, Division 1.
C. Comply with NSF 61, "Drinking Water System Components - Health Effects; Sections 1 through 9" for all components that will be in contact with potable water.

1.05 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to repair or replace components of electric water heaters that fail in materials or workmanship within specified warranty period.

1. Failures include, but are not limited to, the following:
   a. Structural failures including storage tank and supports.
b. Faulty operation of controls.
c. Deterioration of metals, metal finishes, and other materials beyond normal use.

2. Warranty Period(s): From date of Substantial Completion:

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. In other Part 2 Articles where titles below introduce lists, the following requirements apply to product selection:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.02 COMMERCIAL ELECTRIC WATER HEATERS

A. Commercial, Storage Electric Water Heaters: Comply with UL 1453 requirements for storage-tank-type water heaters.

1. Available Manufacturers:
   b. Bock Water Heaters, Inc.
   d. Cemline Corporation.
   e. Electric Heater Company (The); Hubbell Heaters Division.
   f. GSW Water Heating Company.
   g. HESco Industries, Inc.
   h. Lochinvar Corporation.
   i. Precision Boilers.
   j. PVI Industries, LLC.
   k. RECO USA.
   n. Smith, A. O. Water Products Company.
   o. State Industries, Inc.
   a. Tappings: Factory fabricated of materials compatible with tank and piping connections. Attach tappings to tank before testing.
      1) NPS 2 and Smaller: Threaded ends according to ASME B1.20.1.
      2) NPS 2-1/2 and Larger: Flanged ends according to ASME B16.5 for steel and stainless-steel flanges, and according to ASME B16.24 for copper and copper-alloy flanges.
   b. Pressure Rating: 150 psig.
   c. Interior Finish: Comply with NSF 61 barrier materials for potable-water tank linings, including extending lining material into tappings.

3. Factory-Installed Storage-Tank Appurtenances:
   a. Anode Rod: Replaceable magnesium.
   b. Drain Valve: Corrosion-resistant metal complying with ASSE 1005.
   c. Insulation: Comply with ASHRAE/IESNA 90.1.
   d. Jacket: Steel with enameled finish.
   e. Heating Elements: Electric, screw-in or bolt-on immersion type arranged in multiples of three.
      1) Staging: Input not exceeding 18 kW per step.
   f. Temperature Control: Adjustable thermostat.
   g. Safety Controls: High-temperature-limit and low-water cutoff devices or systems.
   h. Relief Valves: ASME rated and stamped and complying with ASME PTC 25.3, for combination temperature and pressure relief valves. Include one or more relief valves with total relieving capacity at least as great as heat input, and include pressure setting less than water heater working-pressure rating. Select one relief valve with sensing element that extends into storage tank.

4. Special Requirements: NSF 5 construction.


2.03 WATER HEATER ACCESSORIES

A. Water Heater Mounting Brackets: Water heater manufacturer's factory-fabricated steel bracket for wall mounting and capable of supporting water heater and water.

B. Drain Pans: Corrosion-resistant metal with raised edge. Include dimensions not less than base of water heater and include drain outlet not less than NPS 3/4.
C. Piping-Type Heat Traps: Field-fabricated piping arrangement according to ASHRAE/IESNA 90.1 or ASHRAE 90.2.

D. Water Regulators: ASSE 1003, water-pressure reducing valve. Set at 25-psig-maximum outlet pressure, unless otherwise indicated.

E. Shock Absorbers: ASSE 1010 or PDI WH 201, Size A water hammer arrester.

PART 3 - EXECUTION

3.01 WATER HEATER INSTALLATION

A. Install commercial water heaters on concrete bases.
   1. Exception: Omit concrete bases for commercial water heaters if installation on stand, bracket, suspended platform, or direct on floor is indicated.
   2. Concrete base construction requirements are specified in Section 22 05 00, Common Work Results for Plumbing.

B. Install water heaters level and plumb, according to layout drawings, original design, and referenced standards. Maintain manufacturer's recommended clearances. Arrange units so controls and devices needing service are accessible.

C. Install combination temperature and pressure relief valves in top portion of storage tanks. Use relief valves with sensing elements that extend into tanks. Extend commercial, water-heater, relief-valve outlet, with drain piping same as domestic water piping in continuous downward pitch, and discharge by positive air gap onto closest floor drain.

D. Install water heater drain piping as indirect waste to spill by positive air gap into open drains or over floor drains. Install hose-end drain valves at low points in water piping for water heaters that do not have tank drains. Refer to Section 22 11 19, Domestic Water Piping Specialties for hose-end drain valves.

E. Install thermometer on outlet piping of water heaters. Refer to Section 22 05 19, Meters and Gages for Plumbing Piping for thermometers.

F. Install water regulator, with integral bypass relief valve, in booster-heater inlet piping and water hammer arrester in booster-heater outlet piping.

G. Install piping-type heat traps on inlet and outlet piping of water heater storage tanks without integral or fitting-type heat traps.

H. Fill water heaters with water.

3.02 CONNECTIONS

A. Install piping adjacent to water heaters to allow service and maintenance. Arrange piping for easy removal of water heaters.

B. Ground equipment according to Section 26 05 26, Grounding and Bounding for Electrical Systems.

C. Connect wiring according to Section 26 05 25, Wire and Cable.
3.03 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections:

1. Leak Test: After installation, test for leaks. Repair leaks and retest until no leaks exist.

2. Operational Test: After electrical circuitry has been energized, confirm proper operation.

3. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

B. Remove and replace water heaters that do not pass tests and inspections and retest as specified above.

3.04 DEMONSTRATION

A. Engage a factory-authorized service representative to train Sound Transit maintenance personnel to adjust, operate, and maintain commercial electric water heaters.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following:
1. Faucets for lavatories and sinks.
2. Flushometers.
3. Toilet seats.
4. Fixture supports.
5. Water closets.
6. Urinals.
7. Lavatories.
8. Service sinks.

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 07 92 00, Joint Sealants.
2. Section 22 05 00, Common Work Results for Plumbing.
3. Section 26 05 25, Wire and Cable.
4. 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. ANSI Z124.5 Standard for Plastic Toilet (Water Closet) Seats
2. American Society of Mechanical Engineers (ASME)
   a. ASME A112.6.1M Supports for Off-the-Floor Plumbing Fixtures for Public Use
   b. ASME A112.18.1 Plumbing Supply Fittings
   c. ASME A112.18.2 2005 Plumbing Waste Fittings
d. ASME A112.18.3 Performance Requirements for Backflow Devices and Systems in Plumbing Fixture Fittings

e. ASME A112.19.2M Vitreous China Plumbing Fixtures and Hydraulic Requirements for Water Closets and Urinals

f. ASME A112.19.5 Trim for Water-Closet Bowls, Tanks and Urinals

g. ASME B1.20.1 Pipe Threads, General Purpose (Inch)

h. ASME B1.20.7 Hose Coupling Screw Threads (Inch)

3. American Society of Safety Engineers (ASSE)

a. ASSE 1001 Performance Requirements for Atmospheric Type Vacuum Breakers

b. ASSE 1011 Performance Requirements for Hose Connection Vacuum Breakers

c. ASSE 1025 Performance Requirements for Diverters for Plumbing Faucets with Hose Spray, Anti-Siphon Type, Residential Applications

4. International Code Council (ICC)

a. ICC A117.1 Standard for Accessible and Usable Buildings and Facilities

5. (NSF)

a. NSF 61 Drinking Water System Components – Health Effects

1.03 DEFINITIONS

A. Accessible Fixture: Plumbing fixture that can be approached, entered, and used by people with disabilities.


1.04 SUBMITTALS

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

B. Product Data: For each type of product indicated.

C. Shop Drawings: Diagram power, signal, and control wiring.

D. Operation and maintenance data.

E. Manufacture’s Warranties

1.05 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable to authorities having jurisdiction, and marked for intended use.


D. NSF Standard: Comply with NSF 61, "Drinking Water System Components--Health Effects," for fixture materials that will be in contact with potable water.

E. Select combinations of fixtures and trim, faucets, fittings, and other components that are compatible.

F. Comply with the following applicable standards and other requirements specified for plumbing fixtures:
   1. Vitreous-China Fixtures: ASME A112.19.2M.

G. Comply with the following applicable standards and other requirements specified for lavatory and sink faucets:
   1. Backflow Protection Devices for Faucets with Side Spray: ASME A112.18.3M.
   2. Backflow Protection Devices for Faucets with Hose-Thread Outlet: ASME A112.18.3M.
   5. Hose-Connection Vacuum Breakers: ASSE 1011.

H. Comply with the following applicable standards and other requirements specified for miscellaneous fittings:

I. Comply with the following applicable standards and other requirements specified for miscellaneous components:
   1. Grab Bars: ASTM F 446.
   3. Off-Floor Fixture Supports: ASME A112.6.1M.

PART 2 - PRODUCTS

2.01 LAVATORY FAUCETS

A. Lavatory Faucets, LV-1:

1. Basis-of-Design Product:  Subject to compliance with requirements, provide the product indicated on Contract Drawings or an approved equal product by one of the following:
   a. American Standard Companies, Inc.
   b. Bradley Corporation.
   c. Chicago Faucets.
   d. Delta Faucet Company.
   e. Eljer.
   f. Elkay Manufacturing Co.
   g. Fisher Manufacturing Co.
   h. Grohe America, Inc.
   i. Just Manufacturing Company.
   j. Kohler Co.
   k. Moen, Inc.
   m. Sayco; a Briggs Plumbing Products, Inc. Company.
   n. Speakman Company.
   o. T & S Brass and Bronze Works, Inc.
   p. Zurn Plumbing Products Group; Commercial Brass Operation.

2. Description:  Single-control mixing valve.  Include hot- and cold-water indicators; coordinate faucet inlets with supplies and fixture holes; coordinate outlet with spout and fixture receptor.
   b. Finish:  Polished chrome plate.
   c. Maximum Flow Rate:  0.5 gpm.
d. Centers: 4 inches Adjustable.
e. Mounting: Deck, exposed.
f. Valve Handle(s): Lever.
g. Inlet(s): NPS 1/2 male shank.
h. Spout: Rigid type.
i. Spout Outlet: Aerator.
k. Drain: GRID
l. Tempering Device: Thermostatic Pressure balance.

2.02 SINK FAUCETS

A. Sink Faucets, MS-1:

1. Available 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. American Standard Companies, Inc.
   b. Bradley Corporation.
   c. Broadway Collection.
   d. Chicago Faucets.
   e. Delta Faucet Company.
   f. Dormont Manufacturing Company.
   g. Eljer.
   h. Elkay Manufacturing Co.
   i. Fisher Manufacturing Co.
   j. Grohe America, Inc.
   k. Just Manufacturing Company.
   l. Kohler Co.
   m. Moen, Inc.
   o. Sayco; a Briggs Plumbing Products, Inc. Company.
   p. Speakman Company.
   q. T & S Brass and Bronze Works, Inc.
2. Description: Service sink faucet with stops in shanks, vacuum breaker, hose-thread outlet, and pail hook. Include hot- and cold-water indicators; coordinate faucet inlets with supplies and fixture holes; coordinate outlet with spout and fixture receptor.

b. Finish: Polished chrome plate.
c. Maximum Flow Rate: 2.5 gpm, unless otherwise indicated.
d. Mixing Valve: Two-lever handle.
e. Backflow Protection Device for Hose Outlet: Required.
g. Centers: 8 inches Adjustable.
h. Mounting: Back/wall, exposed.
i. Handle(s): Lever.
j. Inlet(s): NPS 1/2 male shank.
k. Spout Type: Rigid, solid brass with wall brace Swing, solid brass.
l. Spout Outlet: Aerator Hose thread.
m. Vacuum Breaker: Required.

2.03 FLUSHOMETERS

A. Flushometers, WC-1 UR-1:

1. Available 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. Coyne & Delany Co.
b. Delta Faucet Company.
c. Sloan Valve Company.
d. Zurn Plumbing Products Group; Commercial Brass Operation.

2. Description: Flushometer for urinal water-closet-type fixture. Include brass body with corrosion-resistant internal components, non-hold-open feature, control stop with check valve, vacuum breaker, copper or brass tubing, and polished chrome-plated finish on exposed parts.

a. Internal Design: Diaphragm operation.
b. Style: Exposed.
c. Inlet Size: NPS 1.
d. Trip Mechanism: Oscillating, lever-handle actuator.
e. Consumption: UR 1.0 gal./flush WC 1.6 gal./flush.
f. Tailpiece Size: NPS 1-1/4 and standard length to top of bowl.

2.04 TOILET SEATS

A. Toilet Seats, WC-1:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
   b. Centoco Manufacturing Corp.
   c. Church Seats.
   d. Kohler Co.
   e. Olsonite Corp.
   f. Pressalit A/S.
   g. Sanderson Plumbing Products, Inc.; Beneke Div.
   h. Sperzel.

2. Description: Toilet seat for water-closet-type fixture.
   a. Material: Molded, solid plastic with antimicrobial agent.
   b. Configuration: Open front without cover.
   c. Size: Elongated.
   d. Hinge Type: SS, self-sustaining.
   e. Class: Heavy-duty commercial.

2.05 PROTECTIVE SHIELDING GUARDS

A. Protective Shielding Pipe Covers:

1. Available 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. Engineered Brass Co.
   b. Insul-Tect Products Co.; a Subsidiary of MVG Molded Products.
2. Description: Manufactured plastic wraps for covering plumbing fixture hot- and cold-water supplies and trap and drain piping. Comply with Americans with Disabilities Act (ADA) requirements.

2.06 Fixture Supports

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Josam Company.
2. MIFAB Manufacturing Inc.
4. Tyler Pipe; Wade Div.
5. Watts Drainage Products Inc.; a div. of Watts Industries, Inc.

B. Water-Closet Supports, WC-1:

1. Description: Combination carrier designed for accessible mounting height of wall-mounting, water-closet-type fixture. Include single or double, vertical or horizontal, hub-and-spigot or hubless waste fitting as required for piping arrangement; faceplates; couplings with gaskets; feet; and fixture bolts and hardware matching fixture. Include additional extension coupling, faceplate, and feet for installation in wide pipe space.

C. Urinal Supports, UR-1:

1. Description: Type I, urinal carrier with fixture support plates and coupling with seal and fixture bolts and hardware matching fixture for wall-mounting, urinal-type fixture. Include steel uprights with feet.

D. Lavatory Supports, LV-1:

1. Description: Type I, lavatory carrier with exposed arms and tie rods for wall-mounting, lavatory-type fixture. Include steel uprights with feet.
3. With feet.
2.07 WATER CLOSETS

A. Water Closets, WC-1:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

2. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Contract Drawings or an approved equal product by one of the following:
   a. American Standard Companies, Inc.
   b. Briggs Plumbing Products, Inc.
   c. Capizzi.
   d. Crane Plumbing, L.L.C./Fiat Products.
   e. Eljer.
   f. Kohler Co.
   g. Mansfield Plumbing Products, Inc.
   h. Peerless Pottery, Inc.
   i. Sanitarios Azteca, S.A. de C.V.
   j. St. Thomas Creations.
   k. TOTO USA, Inc.

3. Description: Accessible, floor floor-mounting, floor-outlet, vitreous-china fixture designed for flushometer valve operation.

   a. Bowl Type: Elongated with siphon-vortex design. Include bolt caps matching fixture.
   b. Height: Accessible.
   c. Design Consumption: 1.6 gal./flush.

5. Flushometer: WC-1

6. Toilet Seat: WC-1

2.08 URINALS

A. Urinals, UR-1:

1. Available 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. American Standard Companies, Inc.
b. Briggs Plumbing Products, Inc.
c. Capizzi.
d. Crane Plumbing, L.L.C./Fiat Products.
e. Duravit USA, Inc.
f. Eljer.
g. Kohler Co.
h. Mansfield Plumbing Products, Inc.
i. Peerless Pottery, Inc.
j. Sanitarios Azteca, S.A. de C.V.
k. St. Thomas Creations.
l. TOTO USA, Inc.

2. Description: Accessible, wall-mounting, back-outlet, vitreous-china fixture designed for flushometer valve operation.
   a. Type: Siphon jet with extended shields.
   b. Strainer or Trapway: Separate removable strainer with integral trap.
   c. Design Consumption: 1 gal./flush.
   f. Outlet Size: NPS 2.
   g. Flushometer:
   h. Fixture Support: Urinal chair carrier.

2.09 LAVATORIES

A. Lavatories, LV-1:

1. Available 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. American Standard Companies, Inc.
   b. Barclay Products, Ltd.
   c. Briggs Plumbing Products, Inc.
   d. Crane Plumbing, L.L.C./Fiat Products.
e. Eljer.
f. Gerber Plumbing Fixtures LLC.
g. Kohler Co.
h. Mansfield Plumbing Products, Inc.
i. Peerless Pottery, Inc.
j. Sterling Plumbing Group, Inc.
k. St. Thomas Creations.
l. TOTO USA, Inc.

2. Description: Accessible, wall-mounting, Stainless steel brushed finish.
   a. Type: Shelf back.
   b. Size: 19 by 16 inches rectangular.
   c. Faucet Hole Punching: Three holes, 4-inch centers.
   d. Faucet Hole Location: Top.
   e. Faucet: see faucet.
   g. Drain: Grid.
   h. Location: Near back of bowl.
   i. Drain Piping: chrome-plated, cast-brass P-trap; NPS 1-1/2, 0.045-inch-thick tubular brass waste to wall; and wall escutcheon.
      1) Exception: Omit P-trap if hair interceptor is required.
   j. Protective Shielding Guard(s): LV-1
   k. Fixture Support: Lavatory LV-1

2.10 SERVICE SINKS

A. Service Sinks, SS-1:

   1. Available 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. American Standard Companies, Inc.
      b. Commercial Enameling Company.
      c. Eljer.
      d. Kohler Co.
2. Description: Trap-standard- and wall-mounting, enameled, cast-iron fixture with roll-rim with plain back and rim guard on front and sides.
   a. Size: 24 by 20 inches.
   c. Faucet: Sink.
   d. Drain: Grid with NPS 3 outlet.
   e. Trap Standard: NPS 3 enameled, cast iron with cleanout and floor flange.
   f. Fixture Support: Sink.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Assemble plumbing fixtures, trim, fittings, and other components according to manufacturers' written instructions.

B. Install off-floor supports, affixed to building substrate, for wall-mounting fixtures.
   1. Use carrier supports with waste fitting and seal for back-outlet fixtures.
   2. Use carrier supports without waste fitting for fixtures with tubular waste piping.
   3. Use chair-type carrier supports with rectangular steel uprights for accessible fixtures.

C. Install back-outlet, wall-mounting fixtures onto waste fitting seals and attach to supports.

D. Install floor-mounting fixtures on closet flanges or other attachments to piping or building substrate.

E. Install wall-mounting fixtures with tubular waste piping attached to supports.

F. Install fixtures level and plumb according to roughing-in drawings.

G. Install water-supply piping with stop on each supply to each fixture to be connected to water distribution piping. Attach supplies to supports or substrate within pipe spaces behind fixtures. Install stops in locations where they can be easily reached for operation.

H. Install trap and tubular waste piping on drain outlet of each fixture to be directly connected to sanitary drainage system.

I. Install tubular waste piping on drain outlet of each fixture to be indirectly connected to drainage system.

J. Install flushometer valves for accessible water closets and urinals with handle mounted on wide side of compartment. Install other actuators in locations that are easy for people with disabilities to reach.

K. Install toilet seats on water closets.
L. Install faucet-spout fittings with specified flow rates and patterns in faucet spouts if faucets are not available with required rates and patterns. Include adapters if required.

M. Install water-supply flow-control fittings with specified flow rates in fixture supplies at stop valves.

N. Install faucet flow-control fittings with specified flow rates and patterns in faucet spouts if faucets are not available with required rates and patterns. Include adapters if required.

O. Install shower flow-control fittings with specified maximum flow rates in shower arms.

P. Install traps on fixture outlets.

1. Exception: Omit trap on fixtures with integral traps.

2. Exception: Omit trap on indirect wastes, unless otherwise indicated.

Q. Install escutcheons at piping wall and ceiling penetrations in exposed, finished locations and within cabinets and millwork. Use deep-pattern escutcheons if required to conceal protruding fittings. Escutcheons are specified in Section 22 05 00, Common Work Results for Plumbing.

R. Seal joints between fixtures and walls, floors, and countertops using sanitary-type, one-part, mildew-resistant silicone sealant. Match sealant color to fixture color. Sealants are specified in Section 07 92 00, Joint Sealants.

3.02 CONNECTIONS

A. Piping installation requirements are specified in other Division 22, Plumbing, Sections. Contract Drawings indicate general arrangement of piping, fittings, and specialties.

B. Connect fixtures with water supplies, stops, and risers, and with traps, soil, waste, and vent piping. Use size fittings required to match fixtures.

C. Ground equipment according to Section 26 05 26, Grounding and Bonding for Electrical Systems.

D. Connect wiring according to Section 26 05 25, Wire and Cable.

3.03 FIELD QUALITY CONTROL

A. Verify that installed plumbing fixtures are categories and types specified for locations where installed.

B. Check that plumbing fixtures are complete with trim, faucets, fittings, and other specified components.

C. Inspect installed plumbing fixtures for damage. Replace damaged fixtures and components.

D. Test installed fixtures after water systems are pressurized for proper operation. Replace malfunctioning fixtures and components, then retest. Repeat procedure until units operate properly.

3.04 PROTECTION

A. Provide protective covering for installed fixtures and fittings.
B. Do not allow use of plumbing fixtures for temporary facilities unless approved in writing by Sound Transit.

END OF SECTION
1.01 SUMMARY

A. This Section includes specification for the following:
   1. Piping materials and installation instructions common to most piping systems.
   2. Dielectric fittings.
   3. Mechanical sleeve seals.
   4. Sleeves.
   5. Escutcheons.
   7. Equipment installation requirements common to equipment sections.
   8. Concrete bases.

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 62 00, Non-Shrink Grouting.
   3. Section 05 50 00, Metal Fabrications.
   4. Section 07 84 00, Fire stopping.

1.02 DEFINITIONS

A. Finished Spaces: Spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct chases, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawlspace, and tunnels.

B. Exposed, Interior Installations: Exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.

C. Exposed, Exterior Installations: Exposed to view outdoors or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.

D. Concealed, Interior Installations: Concealed from view and protected from physical contact by building occupants. Examples include above ceilings and chases.
E. Concealed, Exterior Installations: Concealed from view and protected from weather conditions and physical contact by building occupants but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.

1.03 REFERENCES

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

   1. 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
      c. ASME B31 Standards of Pressure Piping

      a. ASTM A53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
      b. ASTM B32 Standard Specification for Solder Metal
      c. ASTM B813 Standard Specification for Liquid and Paste Fluxes for Soldering of Copper and Copper Alloy Tube
      d. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings
      e. ASTM C1107 Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)
      f. ASTM D1785 Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80 and 120
      h. ASTM D2657 Standard Practice for Heat Fusion Joining of Polyolefin Pipe and Fittings
      i. ASTM D2672 Standard Specification for Joints for IPS PVC Pipe Using Solvent Cement
      k. ASTM D2855 Standard Practice for Making Solvent-Cemented Joints with Poly(Vinyl Chloride) (PVC) Pipe and Fittings
      m. ASTM D3212 Standard Specification for Joints for Drain and Sewer Plastic Pipes Using Flexible Elastomeric Seals
      n. ASTM F402 Standard Practice for Safe Handling of Solvent Cements, Primers, and Cleaners Used for Joining Thermoplastic Pipe and Fittings


3. American Welding Society (AWS)
   a. AWS A5.8 Specification for Filler Metals for Brazing and Braze Welding
   b. AWS D1.1 Errata for Structural Welding Code - Steel

B. AWS D10.12 Guide for Welding Mild Steel Pipe

1.04 SUBMITTALS

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

B. Welding certificates.

1.05 QUALITY ASSURANCE

A. Steel Support Welding: Qualify processes and operators according to AWS D1.1, "Structural Welding Code-Steel."

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 Series, "Code for Pressure Piping."
   2. Certify that each welder has passed AWS qualification tests for welding processes involved and that certification is current.

C. Electrical Characteristics for HVAC Equipment: Equipment of higher electrical characteristics may be furnished provided such proposed equipment is approved in writing and connecting electrical services, circuit breakers, and conduit sizes are appropriately modified. If minimum energy ratings or efficiencies are specified, equipment shall comply with requirements.

PART 2 - PRODUCTS

2.01 PIPE, TUBE, AND FITTINGS

A. Refer to individual Division 23, Heating, Ventilation, and Air Conditioning (HVAC), Sections for pipe, tube, and fitting materials and joining methods.

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

2.02 JOINING MATERIALS

A. Refer to individual Division 23, Heating, Ventilation, and Air Conditioning (HVAC), Sections for special joining materials not listed below.

B. Pipe-Flange Gasket Materials: ASME B16.21, nonmetallic, flat, asbestos-free, 1/8-inch maximum thickness unless thickness or specific material is indicated.
C. Plastic, Pipe-Flange Gasket, Bolts, and Nuts: Type and material recommended by piping system manufacturer, unless otherwise indicated.

D. Solder Filler Metals: ASTM B 32, lead-free alloys. Include water-flushable flux according to ASTM B 813.

E. Brazing Filler Metals: AWS A5.8, BCuP Series or BAg1, unless otherwise indicated.


G. Solvent Cements for Joining Plastic Piping:
   1. CPVC Piping: ASTM F 493.
   2. PVC Piping: ASTM D 2564. Include primer according to ASTM F 656.

2.03 DIELECTRIC FITTINGS

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

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

C. Dielectric Unions: Factory-fabricated, union assembly, for 250-psig minimum working pressure at 180 degrees F.

D. Dielectric Flanges: Factory-fabricated, companion-flange assembly, for 150- or 300-psig minimum working pressure as required to suit system pressures.

E. Dielectric Couplings: Galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 300-psig minimum working pressure at 225 degrees F.

F. 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.

2.04 MECHANICAL SLEEVE SEALS

A. Description: Modular sealing element unit, designed for field assembly, to fill annular space between pipe and sleeve.

B. Sealing Elements: EPDM interlocking links shaped to fit surface of pipe. Include type and number required for pipe material and size of pipe.

C. Pressure Plates: Stainless steel. Include two for each sealing element.

D. Connecting Bolts and Nuts: Stainless steel of length required to secure pressure plates to sealing elements. Include one for each sealing element.

2.05 SLEEVES

A. Galvanized-Steel Sheet: 0.0239-inch minimum thickness; round tube closed with welded longitudinal joint.

B. Steel Pipe: ASTM A 53, Type E, Grade B, Schedule 40, galvanized, plain ends.

C. Cast Iron: Cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
D. Stack Sleeve Fittings: Manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.

1. Underdeck Clamp: Clamping ring with set screws.

E. Molded PE: Reusable, PE, tapered-cup shaped, and smooth-outer surface with nailing flange for attaching to wooden forms.

2.06 ESCUTCHEONS

A. Description: Manufactured wall and ceiling escutcheons and floor plates, with an ID to closely fit around pipe, tube, and insulation of insulated piping and an OD that completely covers opening.

B. One-Piece, Deep-Pattern Type: Deep-drawn, box-shaped brass with polished chrome-plated finish.

C. One-Piece, Cast-Brass Type: With set screw.

1. Finish: Polished chrome-plated and rough brass.

D. Split-Casting, Cast-Brass Type: With concealed hinge and set screw.

1. Finish: Polished chrome-plated.

2.07 GROUT

A. Description: ASTM C 1107, Grade B, nonshrink and nonmetallic, dry hydraulic-cement grout.


2. Design Mix: 5000-psi, 28-day compressive strength.


PART 3 - EXECUTION

3.01 PIPING SYSTEMS - COMMON REQUIREMENTS

A. Install piping according to the following requirements and Division 23 , Heating, Ventilation, and Air Conditioning (HVAC), Sections specifying piping systems.

B. Contract Drawings, schematics, and diagrams indicate general location and arrangement of piping systems. Indicated locations and arrangements were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as indicated unless deviations to layout are approved on Coordination Drawings.

C. Install piping in concealed locations, unless otherwise indicated and except in equipment rooms and service areas.

D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
F. Install piping to permit valve servicing.
G. Install piping at indicated slopes.
H. Install piping free of sags and bends.
I. Install fittings for changes in direction and branch connections.
J. Install piping to allow application of insulation.
K. Select system components with pressure rating equal to or greater than system operating pressure.
L. Install escutcheons for penetrations of walls, ceilings, and floors.
M. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs.
N. Aboveground, Exterior-Wall Pipe Penetrations: Seal penetrations using sleeves and mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. Install steel pipe for sleeves smaller than 6 inches in diameter.
   2. Install cast-iron "wall pipes" for sleeves 6 inches and larger in diameter.
   3. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

O. Underground, Exterior-Wall Pipe Penetrations: Install cast-iron "wall pipes" for sleeves. Seal pipe penetrations using mechanical sleeve seals. Select sleeve size to allow for 1-inch annular clear space between pipe and sleeve for installing mechanical sleeve seals.
   1. Mechanical Sleeve Seal Installation: Select type and number of sealing elements required for pipe material and size. Position pipe in center of sleeve. Assemble mechanical sleeve seals and install in annular space between pipe and sleeve. Tighten bolts against pressure plates that cause sealing elements to expand and make watertight seal.

P. Fire-Barrier Penetrations: Maintain indicated fire rating of walls, partitions, ceilings, and floors at pipe penetrations. Seal pipe penetrations with firestop materials. Refer to Section 07 84 00, Firestopping, for materials.
Q. Verify final equipment locations for roughing-in.
R. Refer to equipment specifications in other Sections of these Contract Specifications for roughing-in requirements.

3.02 PIPING JOINT CONSTRUCTION

A. Join pipe and fittings according to the following requirements and Division 23, Heating, Ventilation, and Air Conditioning (HVAC), Sections specifying piping systems.

B. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
C. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.

D. Soldered Joints: Apply ASTM B 813, water-flushable flux, unless otherwise indicated, to tube end. Construct joints according to ASTM B 828 or CDA’s "Copper Tube Handbook," using lead-free solder alloy complying with ASTM B 32.


F. 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:
   1. Apply appropriate tape or thread compound to external pipe threads unless dry seal threading is specified.
   2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

G. Welded Joints: Construct joints according to AWS D10.12, using qualified processes and welding operators according to Article 1.04, herein.

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

I. Plastic Piping Solvent-Cement Joints: Clean and dry joining surfaces. Join pipe and fittings according to the following:
   1. Comply with ASTM F 402, for safe-handling practice of cleaners, primers, and solvent cements.
   2. CPVC Piping: Join according to ASTM D 2846/D 2846M Appendix.
   3. PVC Pressure Piping: Join schedule number ASTM D 1785, PVC pipe and PVC socket fittings according to ASTM D 2672. Join other-than-schedule-number PVC pipe and socket fittings according to ASTM D 2855.
   4. PVC Nonpressure Piping: Join according to ASTM D 2855.

J. Plastic Pressure Piping Gasketed Joints: Join according to ASTM D 3139.

K. Plastic Nonpressure Piping Gasketed Joints: Join according to ASTM D 3212.

L. PE Piping Heat-Fusion Joints: Clean and dry joining surfaces by wiping with clean cloth or paper towels. Join according to ASTM D 2657.
   1. Plain-End Pipe and Fittings: Use butt fusion.
   2. Plain-End Pipe and Socket Fittings: Use socket fusion.

M. Fiberglass Bonded Joints: Prepare pipe ends and fittings, apply adhesive, and join according to pipe manufacturer’s written instructions.
3.03 PIPING CONNECTIONS
A. Make connections according to the following, unless otherwise indicated:
   1. Install unions, in piping NPS 2 and smaller, adjacent to each valve and at final connection to each piece of equipment.
   2. Install flanges, in piping NPS 2-1/2 and larger, adjacent to flanged valves and at final connection to each piece of equipment.
   3. Dry Piping Systems: Install dielectric unions and flanges to connect piping materials of dissimilar metals.

3.04 EQUIPMENT INSTALLATION - COMMON REQUIREMENTS
A. Install equipment to allow maximum possible headroom unless specific mounting heights are not indicated.
B. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated.
C. Install HVAC 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.
D. Install equipment to allow right of way for piping installed at required slope.

3.05 CONCRETE BASES
A. Concrete Bases: Anchor equipment to concrete base according to equipment manufacturer's written instructions and according to seismic requirements of this project.
   1. Construct concrete bases of dimensions indicated, but not less than 4 inches larger in both directions than supported unit.
   2. Install dowel rods to connect concrete base to concrete floor. Unless otherwise indicated, install dowel rods on 18-inch centers around the full perimeter of the base.
   3. Install epoxy-coated anchor bolts for supported equipment that extend through concrete base, and anchor into structural concrete floor.
   4. Place and secure anchorage devices. Use supported equipment manufacturer's setting drawings, templates, diagrams, instructions, and directions furnished with items to be embedded.
   5. Install anchor bolts to elevations required for proper attachment to supported equipment.
   6. Install anchor bolts according to anchor-bolt manufacturer's written instructions.
   7. Use 3000-psi, 28-day compressive-strength concrete and reinforcement as specified in Section 03 05 15, Portland Cement Concrete.
3.06 ERECTION OF METAL SUPPORTS AND ANCHORAGES
   A. Refer to Section 05 50 00, Metal Fabrications, for structural steel.
   B. Cut, fit, and place miscellaneous metal supports accurately in location, alignment, and elevation to support and anchor HVAC materials and equipment.
   C. Field Welding: Comply with AWS D1.1.

3.07 ERECTION OF WOOD SUPPORTS AND ANCHORAGES
   A. Cut, fit, and place wood grounds, nailers, blocking, and anchorages to support, and anchor HVAC materials and equipment.
   B. Select fastener sizes that will not penetrate members if opposite side will be exposed to view or will receive finish materials. Tighten connections between members. Install fasteners without splitting wood members.
   C. Attach to substrates as required to support applied loads.

3.08 GROUTING
   A. Mix and install grout as specified in Section 03 62 00, Non-Shrink Grouting, for HVAC equipment base bearing surfaces, pump and other equipment base plates, and anchors.
   B. Clean surfaces that will come into contact with grout.
   C. Provide forms as required for placement of grout.
   D. Avoid air entrapment during placement of grout.
   E. Place grout, completely filling equipment bases.
   F. Place grout on concrete bases and provide smooth bearing surface for equipment.
   G. Place grout around anchors.
   H. Cure placed grout.

END OF SECTION
SECTION 23 05 13
COMMON MOTOR REQUIREMENTS FOR HVAC EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY

A. Section includes general requirements for single-phase and polyphase, general-purpose, horizontal, small and medium, squirrel-cage induction motors for use on ac power systems up to 600 V and installed at equipment manufacturer's factory or shipped separately by equipment manufacturer for field installation.

1.02 REFERENCES

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

1. National Electrical Manufacturers Association (NEMA)
   a. NEMA MG 1 Motors and Generators

2. Institute of Electrical and Electronics Engineers (IEEE)
   a. IEEE 841 Standard for the Petroleum and Chemical Industry-Severe Duty Totally Enclosed Fan Cooled (TEFC) Squirrel Cage Induction Motors-Up to and Including 500 hp

1.03 COORDINATION

A. Coordinate features of motors, installed units, and accessory devices to be compatible with the following:

1. Motor controllers.

2. Torque, speed, and horsepower requirements of the load.

3. Ratings and characteristics of supply circuit and required control sequence.

4. Ambient and environmental conditions of installation location.

PART 2 - PRODUCTS

2.01 GENERAL MOTOR REQUIREMENTS

A. Comply with requirements in this Section except when stricter requirements are specified in HVAC equipment schedules or Sections.

B. Comply with NEMA MG 1 unless otherwise indicated.

C. Comply with IEEE 841 for severe-duty motors.
2.02 MOTOR CHARACTERISTICS
A. Duty: Continuous duty at ambient temperature of 140 degrees F and at altitude of 3300 feet above sea level.

B. Capacity and Torque Characteristics: Sufficient to start, accelerate, and operate connected loads at designated speeds, at installed altitude and environment, with indicated operating sequence, and without exceeding nameplate ratings or considering service factor.

2.03 POLYPHASE MOTORS
A. Description: NEMA MG 1, Design B, medium induction motor.

B. Efficiency: Energy efficient, as defined in NEMA MG 1.

C. Service Factor: 1.15.

D. Multispeed Motors: Variable torque.
   1. For motors with 2:1 speed ratio, consequent pole, single winding.
   2. For motors with other than 2:1 speed ratio, separate winding for each speed.

E. Multispeed Motors: Separate winding for each speed.

F. Rotor: Random-wound, squirrel cage.

G. Bearings: Regreasable, shielded, antifriction ball bearings suitable for radial and thrust loading.

H. Temperature Rise: Match insulation rating.

I. Insulation: Class F.

J. Code Letter Designation:
   1. Motors 15 HP and Larger: NEMA starting Code F or Code G.
   2. Motors Smaller than 15 HP: Manufacturer's standard starting characteristic.

K. Enclosure Material: Cast iron for motor frame sizes 324T and larger; rolled steel for motor frame sizes smaller than 324T.

2.04 POLYPHASE MOTORS WITH ADDITIONAL REQUIREMENTS
A. Motors Used with Reduced-Voltage and Multispeed Controllers: Match wiring connection requirements for controller with required motor leads. Provide terminals in motor terminal box, suited to control method.

B. Motors Used with Variable Frequency Controllers: Ratings, characteristics, and features coordinated with and approved by controller manufacturer.

1. Windings: Copper magnet wire with moisture-resistant insulation varnish, designed and tested to resist transient spikes, high frequencies, and short time rise pulses produced by pulse-width modulated inverters.

2. Energy- and Premium-Efficient Motors: Class B temperature rise; Class F insulation.
3. Inverter-Duty Motors: Class F temperature rise; Class H insulation.

4. Thermal Protection: Comply with NEMA MG 1 requirements for thermally protected motors.

C. Severe-Duty Motors: Comply with IEEE 841, with 1.15 minimum service factor.

2.05 SINGLE-PHASE MOTORS

A. Motors larger than 1/20 hp will be one of the following, to suit starting torque and requirements of specific motor application:

1. Permanent-split capacitor.
2. Split phase.
3. Capacitor start, inductor run.
4. Capacitor start, capacitor run.

B. Multispeed Motors: Variable-torque, permanent-split-capacitor type.

C. Bearings: Prelubricated, antifriction ball bearings or sleeve bearings suitable for radial and thrust loading.

D. Motors 1/20 HP and Smaller: Shaded-pole type.

E. Thermal Protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. The thermal-protection device automatically reset when motor temperature returns to normal range.

PART 3 - EXECUTION (NOT USED)

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following:
   1. Steel pipe hangers and supports.
   2. Trapeze pipe hangers.
   3. Metal framing systems.
   4. Thermal-hanger shield inserts.
   5. Fastener systems.
   6. Equipment supports.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. Boiler and Pressure Vessel Code (BPVC), Section IX, Welding and Brazing Qualifications
      b. ASME B31.3 Power Piping and Process Piping
      c. ASME B31.9 Building Services Piping
   2. Manufacturers Standardization Society (MSS)
      a. MSS SP-89 Pipe Hangers and Supports – Fabrication and Installation Practices
      b. MSS SP-90 Guidelines on Terminology for Pipe Hangers and Supports
      c. MSS SP-58 Pipe Hangers and Supports – Materials, Design and Manufacture
      d. MSS SP-69 Pipe Hangers and Supports – Selection and Application
      a. ASTM C 533 Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation
b. ASTM C 552 Standard Specification for Cellular Glass Thermal Insulation

c. ASTM A 36/A 36M Standard Specification for Carbon Structural Steel

d. ASTM C 1107 Standard Specification for Packaged Dry, Hydraulic-Cement Grout (Nonshrink)

e. ASTM A 780 Standard Specification for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

4. Metal Framing Manufacturers Association (MFMA)
   a. MFMA 102 Guidelines for the use of Metal Framing

5. American Welding Society (AWS)
   a. AWS D1.1 Structural Welding Code

1.03 DEFINITIONS

A. Terminology: As defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."

1.04 PERFORMANCE REQUIREMENTS

A. Design seismic supports for multiple pipes capable of supporting combined weight of supported systems, system contents, and test water.

B. Design equipment seismic supports capable of supporting combined operating weight of supported equipment and connected systems and components.

C. Design seismic-restraint hangers and supports for piping and equipment and obtain approval from Resident Engineer and the Seattle Code authority having jurisdiction.

1.05 SUBMITTALS

A. Product Data: For the following:
   1. Steel pipe hangers and supports.
   2. Thermal-hanger shield inserts.
   3. Powder-actuated fastener systems.

B. Shop Drawings: Signed and sealed by a qualified professional engineer. Show fabrication and installation details and include calculations for the following:
   1. Trapeze pipe hangers. Include Product Data for components.
   2. Metal framing systems. Include Product Data for components.
   3. Equipment supports.

C. Welding certificates.
1.06 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.02 STEEL PIPE SEISMIC HANGERS AND SUPPORTS

A. Description: MSS SP-58, Types 1 through 58, factory-fabricated components. Refer to Part 3, Seismic Hanger and Support Applications, Article for where to use specific hanger and support types.

B. Available Manufacturers:

1. AAA Technology & Specialties Co., Inc.
2. Bergen-Power Pipe Supports.
4. Carpenter & Paterson, Inc.
5. Empire Industries, Inc.
6. ERICO/Michigan Hanger Co.
7. Globe Pipe Hanger Products, Inc.
8. Grinnell Corp.
9. GS Metals Corp.
11. PHD Manufacturing, Inc.
12. PHS Industries, Inc.
13. Piping Technology & Products, Inc.
14. Tolco Inc.

C. Galvanized, Metallic Coatings: Pregalvanized or hot dipped.

D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

E. Padded Hangers: Hanger with fiberglass or other pipe insulation pad or cushion for support of bearing surface of piping.
2.03 TRAPEZE PIPE HANGERS
A. Description: MSS SP-69, Type 59, shop- or field-fabricated pipe-support assembly made from structural-steel shapes with MSS SP-58 hanger rods, nuts, saddles, and U-bolts.

2.04 METAL FRAMING SYSTEMS
A. Description: MFMA-3, shop- or field-fabricated pipe-support assembly made of steel channels and other components.
B. Available Manufacturers:
   2. ERICO/Michigan Hanger Co.; ERISTRUT Div.
   3. GS Metals Corp.
   5. Thomas & Betts Corporation.
   6. Tolco Inc.
   7. Unistrut Corp.; Tyco International, Ltd.
C. Coatings: Manufacturer's standard finish, unless bare metal surfaces are indicated.
D. Nonmetallic Coatings: Plastic coating, jacket, or liner.

2.05 THERMAL-HANGER SHIELD INSERTS
A. Description: 100-psig- minimum, compressive-strength insulation insert encased in sheet metal shield.
B. Available Manufacturers:
   1. Carpenter & Paterson, Inc.
   2. ERICO/Michigan Hanger Co.
   3. PHS Industries, Inc.
   4. Pipe Shields, Inc.
   5. Rilco Manufacturing Company, Inc.
   6. Value Engineered Products, Inc.
C. Insulation-Insert Material for Cold Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass with vapor barrier.
D. Insulation-Insert Material for Hot Piping: Water-repellent treated, ASTM C 533, Type I calcium silicate or ASTM C 552, Type II cellular glass.
E. For Trapeze or Clamped Systems: Insert and shield shall cover entire circumference of pipe.
F. For Clevis or Band Hangers: Insert and shield shall cover lower 180 degrees of pipe.
G. Insert Length: Extend 2 inches beyond sheet metal shield for piping operating below ambient air temperature.

2.06 SEISMIC FASTENER SYSTEMS

A. Powder-Actuated Fasteners: Threaded-steel stud, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Available Manufacturers:
   a. Hilti, Inc.
   b. ITW Ramset/Red Head.
   c. Masterset Fastening Systems, Inc.
   d. MKT Fastening, LLC.
   e. Powers Fasteners.

B. Mechanical-Expansion Anchors: Insert-wedge-type stainless steel, for use in hardened portland cement concrete with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

1. Available Manufacturers:
   b. Empire Industries, Inc.
   c. Hilti, Inc.
   d. ITW Ramset/Red Head.
   e. MKT Fastening, LLC.
   f. Powers Fasteners.

2.07 EQUIPMENT SUPPORTS

A. Description: Welded, shop- or field-fabricated equipment support made from structural-steel shapes.

2.08 MISCELLANEOUS MATERIALS

A. Structural Steel: ASTM A 36/A 36M, steel plates, shapes, and bars; black and galvanized.

B. Grout: ASTM C 1107, factory-mixed and -packaged, dry, hydraulic-cement, nonshrink and nonmetallic grout; suitable for interior and exterior applications.


2. Design Mix: 5000-psi, 28-day compressive strength.
PART 3 - EXECUTION

3.01 SEISMIC HANGER AND SUPPORT APPLICATIONS

A. Specific hanger and support requirements are specified in Sections specifying piping systems and equipment.

B. Comply with MSS SP-69 for pipe hanger selections and applications that are not specified in piping system Sections.

C. Use hangers and supports with galvanized, metallic coatings for piping and equipment that will not have field-applied finish.

D. Use nonmetallic coatings on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

E. Use padded hangers for piping that is subject to scratching.

F. Horizontal-Piping Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

   1. Adjustable, Steel Clevis Hangers (MSS Type 1): For suspension of noninsulated or insulated stationary pipes, NPS 1/2 to NPS 30.
   2. Yoke-Type Pipe Clamps (MSS Type 2): For suspension of 120 to 450 deg F pipes, NPS 4 to NPS 16, requiring up to 4 inches of insulation.
   3. Carbon- or Alloy-Steel, Double-Bolt Pipe Clamps (MSS Type 3): For suspension of pipes, NPS 3/4 to NPS 24, requiring clamp flexibility and up to 4 inches of insulation.
   4. Adjustable, Steel Band Hangers (MSS Type 7): For suspension of noninsulated stationary pipes, NPS 1/2 to NPS 8.
   5. U-Bolts (MSS Type 24): For support of heavy pipes, NPS 1/2 to NPS 30.
   6. Pipe Saddle Supports (MSS Type 36): For support of pipes, NPS 4 to NPS 36, with steel pipe base stanchion support and cast-iron floor flange.
   7. Single Pipe Rolls (MSS Type 41): For suspension of pipes, NPS 1 to NPS 30, from 2 rods if longitudinal movement caused by expansion and contraction might occur.
   8. Complete Pipe Rolls (MSS Type 44): For support of pipes, NPS 2 to NPS 42, if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.

G. Vertical-Piping Clamps: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

   1. Extension Pipe or Riser Clamps (MSS Type 8): For support of pipe risers, NPS 3/4 to NPS 20.
   2. Carbon- or Alloy-Steel Riser Clamps (MSS Type 42): For support of pipe risers, NPS 3/4 to NPS 20, if longer ends are required for riser clamps.
H. Hanger-Rod Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Turnbuckles (MSS Type 13): For adjustment up to 6 inches for heavy loads.
2. Steel Clevises (MSS Type 14): For 120 to 450 deg F piping installations.

I. Building Attachments: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel or Malleable Concrete Inserts (MSS Type 18): For upper attachment to suspend pipe hangers from concrete ceiling.
2. Top-Beam C-Clamps (MSS Type 19): For use under roof installations with bar Joist construction to attach to top flange of structural shape.
3. Side-Beam or Channel Clamps (MSS Type 20): For attaching to bottom flange of beams, channels, or angles.
4. Center-Beam Clamps (MSS Type 21): For attaching to center of bottom flange of beams.
5. Welded Beam Attachments (MSS Type 22): For attaching to bottom of beams if loads are considerable and rod sizes are large.
6. C-Clamps (MSS Type 23): For structural shapes.
7. Welded-Steel Brackets: For support of pipes from below, or for suspending from above by using clip and rod. Use one of the following for indicated loads:
   a. Light (MSS Type 31): 750 lb.
   b. Medium (MSS Type 32): 1500 lb.
   c. Heavy (MSS Type 33): 3000 lb.
8. Side-Beam Brackets (MSS Type 34): For sides of steel or wooden beams.
9. Plate Lugs (MSS Type 57): For attaching to steel beams if flexibility at beam is required.

J. Saddles and Shields: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Steel Pipe-Covering Protection Saddles (MSS Type 39): To fill interior voids with insulation that matches adjoining insulation.
2. Protection Shields (MSS Type 40): Of length recommended in writing by manufacturer to prevent crushing insulation.
3. Thermal-Hanger Shield Inserts: For supporting insulated pipe.

K. Spring Hangers and Supports: Unless otherwise indicated and except as specified in piping system Sections, install the following types:

1. Spring Cushions (MSS Type 48): For light loads if vertical movement does not exceed 1-1/4 inches.
2. **Spring-Cushion Roll Hangers (MSS Type 49):** For equipping Type 41 roll hanger with springs.

3. **Variable-Spring Base Supports (MSS Type 52):** Preset to indicated load and limit variability factor to 25 percent to absorb expansion and contraction of piping system from base support.

L. Comply with MSS SP-69 for trapeze pipe hanger selections and applications that are not specified in piping system Sections.

M. Comply with MFMA-102 for metal framing system selections and applications that are not specified in piping system Sections.

N. Use mechanical-expansion anchors instead of building attachments where required in concrete construction.

### 3.02 HANGER AND SUPPORT INSTALLATION

A. **Steel Pipe Hanger Installation:** Comply with MSS SP-69 and MSS SP-89. Install hangers, supports, clamps, and attachments as required to properly support piping from building structure.

B. **Trapeze Pipe Hanger Installation:** Comply with MSS SP-69 and MSS SP-89. Arrange for grouping of parallel runs of horizontal piping and support together on field-fabricated trapeze pipe hangers.

1. **Pipes of Various Sizes:** Support together and space trapezes for smallest pipe size or install intermediate supports for smaller diameter pipes as specified above for individual pipe hangers.

2. **Field fabricate from** ASTM A 36/A 36M, steel shapes selected for loads being supported. Weld steel according to AWS D1.1.

C. **Metal Framing System Installation:** Arrange for grouping of parallel runs of piping and support together on field-assembled metal framing systems.

D. **Thermal-Hanger Shield Installation:** Install in pipe hanger or shield for insulated piping.

E. **Fastener System Installation:**

1. Install powder-actuated fasteners in concrete after concrete is placed and completely cured. Use operators that are licensed by powder-actuated tool manufacturer. Install fasteners according to powder-actuated tool manufacturer's operating manual.

2. Install mechanical-expansion anchors in concrete after concrete is placed and completely cured. Install fasteners according to manufacturer's written instructions.

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

G. **Equipment Support Installation:** Fabricate from welded-structural-steel shapes.

H. 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 expansion joints, expansion loops, expansion bends, and similar units.
I. Install lateral bracing with pipe hangers and supports to prevent swaying.

J. Install building attachments within concrete slabs or attach to structural steel. Install additional attachments at concentrated loads, including valves, flanges, and strainers, NPS 2-1/2 and larger and at changes in direction of piping. Install concrete inserts before concrete is placed; fasten inserts to forms and install reinforcing bars through openings at top of inserts.

K. Load Distribution: Install hangers and supports so piping live and dead loads and stresses from movement will not be transmitted to connected equipment.

L. Pipe Slopes: Install hangers and supports to provide indicated pipe slopes and so maximum pipe deflections allowed by ASME B31.1 (for power piping) and ASME B31.9 (for building services piping) are not exceeded.

M. Insulated Piping: Comply with the following:
   1. Attach clamps and spacers to piping.
      a. Piping Operating above Ambient Air Temperature: Clamp may project through insulation.
      b. Piping Operating below Ambient Air Temperature: Use thermal-hanger shield insert with clamp sized to match OD of insert.
      c. Do not exceed pipe stress limits according to ASME B31.1 for power piping and ASME B31.9 for building services piping.
   2. Install MSS SP-58, Type 39, protection saddles if insulation without vapor barrier is indicated. Fill interior voids with insulation that matches adjoining insulation.
   3. Install MSS SP-58, Type 40, protective shields on cold piping with vapor barrier. Shields shall span an arc of 180 degrees.
   4. Shield Dimensions for Pipe: Not less than the following:
      a. NPS 1/4 to NPS 3-1/2: 12 inches long and 0.048 inch thick.
      b. NPS 4: 12 inches long and 0.06 inch thick.
      c. NPS 5 and NPS 6: 18 inches long and 0.06 inch thick.
      d. NPS 8 to NPS 14: 24 inches long and 0.075 inch thick.
      e. NPS 16 to NPS 24: 24 inches long and 0.105 inch thick.
   5. Pipes NPS 8 and Larger: Include wood inserts.
   6. Insert Material: Length at least as long as protective shield.
   7. Thermal-Hanger Shields: Install with insulation same thickness as piping insulation.

3.03 EQUIPMENT SUPPORTS

A. Fabricate structural-steel stands to suspend equipment from structure overhead or to support equipment above floor.

B. Grouting: Place grout under supports for equipment and make smooth bearing surface.
C. Provide lateral bracing, to prevent swaying, for equipment supports.

3.04 METAL FABRICATIONS

A. Cut, drill, and fit miscellaneous metal fabrications for trapeze pipe hangers and equipment supports.

B. Fit exposed connections together to form hairline joints. Field weld connections that cannot be shop welded because of shipping size limitations.

C. Field Welding: Comply with AWS D1.1 procedures for shielded metal arc welding, appearance and quality of welds, and methods used in correcting welding work, and with 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. Finish welds at exposed connections so no roughness shows after finishing and contours of welded surfaces match adjacent contours.

3.05 ADJUSTING

A. Hanger Adjustments: Adjust hangers to distribute loads equally on attachments and to achieve indicated slope of pipe.

3.06 PAINTING

A. Galvanized Surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

END OF SECTION
SECTION 23 05 48

VIBRATION AND SEISMIC CONTROLS FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specification for the following:

1. Isolation pads.
2. Isolation mounts.
3. Restrained elastomeric isolation mounts.
4. Freestanding and restrained spring isolators.
5. Housed spring mounts.
6. Elastomeric hangers.
7. Spring hangers.
8. Spring hangers with vertical-limit stops.
9. Pipe riser resilient supports.
10. Resilient pipe guides.
11. Restraining braces and cables.

1.02 REFERENCES

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

1. American Welding Society (AWS)
   a. AWS D1.1/D1.1M Errata for Structural Welding Code – Steel

2. American Association of State Highway and Transportation Officials (AASHTO)
   a. AASHTO M-251 Standard Specification for Plain and Laminated Elastomeric Bridge Bearings

   a. ASTM A 492 Standard Specification for Stainless Steel Rope Wire
   b. ASTM e 488 Standard Test Methods for Strength of Anchors in Concrete and Masonry Elements

4. Manufacturers Standardization Society (MSS)
1.03 PERFORMANCE REQUIREMENTS

A. Wind-Restraint Loading:
   1. Basic Wind Speed: As indicated on Contract Drawings.
   2. Building Classification Category: As indicated on Contract Drawings.
   3. Minimum 10 lb/sq. ft. multiplied by the maximum area of the HVAC component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

B. Seismic-Restraint Loading:
   1. Site Class as Defined in the IBC As indicated on Contract Drawings.
   2. Assigned Seismic Use Group or Building Category as Defined in the IBC: As indicated on Contract Drawings for structural.
   3. Design Spectral Response Acceleration at Short Periods (0.2 Second): Match Contract Drawings for structural.

1.04 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each product indicated.
C. Delegated-Design Submittal: For vibration isolation and seismic-restraint calculations and details indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
D. Welding certificates.
E. Qualification Data: For professional engineer.
F. Field quality-control test reports.

1.05 QUALITY ASSURANCE

A. Comply with seismic-restraint requirements in the IBC unless requirements in this Section are more stringent.
B. Welding: Qualify procedures and personnel according to AWS D1.1/D1.1M, "Structural Welding Code - Steel."

C. Seismic-restraint devices shall have horizontal and vertical load testing and analysis and shall bear anchorage preapproval OPA number from OSHPD, preapproval by ICC-ES, or preapproval by another agency acceptable to authorities having jurisdiction, showing maximum seismic-restraint ratings. Ratings based on independent testing are preferred to ratings based on calculations. If preapproved ratings are not available, submittals based on independent testing are preferred. Calculations (including combining shear and tensile loads) to support seismic-restraint designs must be signed and sealed by a qualified professional engineer.

PART 2 - PRODUCTS

2.01 VIBRATION ISOLATORS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Ace Mountings Co., Inc.
2. Amber/Booth Company, Inc.
4. Isolation Technology, Inc.
7. Vibration Eliminator Co., Inc.
8. Vibration Isolation.

B. Pads: Arranged in single or multiple layers of sufficient stiffness for uniform loading over pad area, molded with a nonslip pattern and galvanized-steel baseplates, and factory cut to sizes that match requirements of supported equipment.

1. Resilient Material: Oil- and water-resistant neoprene.

C. Mounts: Double-deflection type, with molded, oil-resistant rubber, hermetically sealed compressed fiberglass, or neoprene isolator elements with factory-drilled, encapsulated top plate for bolting to equipment and with baseplate for bolting to structure. Color-code or otherwise identify to indicate capacity range.

1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.
D. Restrained Mounts: All-directional mountings with seismic restraint.

1. Materials: Cast-ductile-iron or welded steel housing containing two separate and opposing, oil-resistant rubber or neoprene elements that prevent central threaded element and attachment hardware from contacting the housing during normal operation.

2. Neoprene: Shock-absorbing materials compounded according to the standard for bridge-bearing neoprene as defined by AASHTO.

E. Spring Isolators: Freestanding, laterally stable, open-spring isolators.

1. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

2. Minimum Additional Travel: 50 percent of the required deflection at rated load.

3. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

4. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

5. Baseplates: Factory drilled for bolting to structure and bonded to 1/4-inch-thick, rubber isolator pad attached to baseplate underside. Baseplates shall limit floor load to 500 psig.

6. Top Plate and Adjustment Bolt: Threaded top plate with adjustment bolt and cap screw to fasten and level equipment.

F. Restrained Spring Isolators: Freestanding, steel, open-spring isolators with seismic or limit-stop restraint.

1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to weight being removed; factory-drilled baseplate bonded to 1/4-inch-thick, neoprene or rubber isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.

2. Restraint: Seismic or limit stop as required for equipment and authorities having jurisdiction.

3. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

4. Minimum Additional Travel: 50 percent of the required deflection at rated load.

5. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

6. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

G. Housed Spring Mounts: Housed spring isolator with integral seismic snubbers.

1. Housing: Ductile-iron or steel housing to provide all-directional seismic restraint.

2. Base: Factory drilled for bolting to structure.

3. Snubbers: Vertically adjustable to allow a maximum of 1/4-inch travel up or down before contacting a resilient collar.
H. Elastomeric Hangers: Single or double-deflection type, fitted with molded, oil-resistant elastomeric isolator elements bonded to steel housings with threaded connections for hanger rods. Color-code or otherwise identify to indicate capacity range.

I. Spring Hangers: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression.

1. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

3. Minimum Additional Travel: 50 percent of the required deflection at rated load.

4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

6. Elastomeric Element: Molded, oil-resistant rubber or neoprene. Steel-washer-reinforced cup to support spring and bushing projecting through bottom of frame.

7. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

J. Spring Hangers with Vertical-Limit Stop: Combination coil-spring and elastomeric-insert hanger with spring and insert in compression and with a vertical-limit stop.

1. Frame: Steel, fabricated for connection to threaded hanger rods and to allow for a maximum of 30 degrees of angular hanger-rod misalignment without binding or reducing isolation efficiency.

2. Outside Spring Diameter: Not less than 80 percent of the compressed height of the spring at rated load.

3. Minimum Additional Travel: 50 percent of the required deflection at rated load.

4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.

5. Overload Capacity: Support 200 percent of rated load, fully compressed, without deformation or failure.

6. Elastomeric Element: Molded, oil-resistant rubber or neoprene.

7. Adjustable Vertical Stop: Steel washer with neoprene washer “up-stop” on lower threaded rod.

8. Self-centering hanger rod cap to ensure concentricity between hanger rod and support spring coil.

K. Pipe Riser Resilient Support: All-directional, acoustical pipe anchor consisting of 2 steel tubes separated by a minimum of 1/2-inch-thick neoprene. Include steel and neoprene vertical-limit stops arranged to prevent vertical travel in both directions. Design support for a maximum load on the isolation material of 500 psig and for equal resistance in all directions.
L. Resilient Pipe Guides: Telescopic arrangement of 2 steel tubes or post and sleeve arrangement separated by a minimum of 1/2-inch thick neoprene. Where clearances are not readily visible, a factory-set guide height with a shear pin to allow vertical motion due to pipe expansion and contraction shall be fitted. Shear pin shall be removable and reinsertable to allow for selection of pipe movement. Guides shall be capable of motion to meet location requirements.

2.02 SEISMIC-RESTRAINT DEVICES

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. Amber/Booth Company, Inc.
2. California Dynamics Corporation.
3. Cooper B-Line, Inc.; a division of Cooper Industries.
4. Hilti, Inc.
7. Mason Industries.
8. TOLCO Incorporated; a brand of NIBCO INC.
9. Unistrut; Tyco International, Ltd.

B. General Requirements for Restraint Components: Rated strengths, features, and applications shall be as defined in reports by an Independent Testing Laboratory acceptable to authorities having jurisdiction.

1. 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.

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

D. Restraint Cables: ASTM A 492 stainless-steel cables with end connections made of steel assemblies with thimbles, brackets, swivel, and bolts designed for restraining cable service; and with a minimum of two clamping bolts for cable engagement.

E. Hanger Rod Stiffener: Steel tube or steel slotted-support-system sleeve with internally bolted connections to hanger rod.

F. Bushings for Floor-Mounted Equipment Anchor Bolts: Neoprene bushings designed for rigid equipment mountings, and matched to type and size of anchor bolts and studs.

G. Resilient Isolation Washers and Bushings: One-piece, molded, oil- and water-resistant neoprene, with a flat washer face.
H. Mechanical Anchor Bolts: Drilled-in and stud-wedge or female-wedge type in zinc-coated steel for interior applications and stainless steel for exterior applications. Select anchor bolts with strength required for anchor and as tested according to ASTM E 488. Minimum length of eight times diameter.

PART 3 - EXECUTION

3.01 APPLICATIONS

A. Multiple Pipe Supports: Secure pipes to trapeze member with clamps approved for application by an Independent Testing Laboratory acceptable to authorities having jurisdiction.

B. Hanger Rod Stiffeners: Install hanger rod stiffeners where indicated or scheduled on Contract Drawings to receive them and where required to prevent buckling of hanger rods due to seismic forces.

C. Strength of Support and Seismic-Restraint Assemblies: Where not indicated, select sizes of components so strength will be adequate to carry present and future static and seismic loads within specified loading limits.

3.02 VIBRATION-CONTROL AND SEISMIC-RESTRAINT DEVICE INSTALLATION

A. Comply with requirements in Section 07 72 00, Roof Accessories, for installation of roof curbs, equipment supports, and roof penetrations.

B. Equipment Restraints:
   1. Install resilient bolt isolation washers on equipment anchor bolts where clearance between anchor and adjacent surface exceeds 0.125 inch.
   2. Install seismic-restraint devices using methods approved by an Independent Testing Laboratory acceptable to authorities having jurisdiction providing required submittals for component.

C. Piping Restraints:
   1. Comply with requirements in MSS SP-127.
   2. Space lateral supports a maximum of 40 feet o.c., and longitudinal supports a maximum of 80 feet o.c.
   3. Brace a change of direction longer than 12 feet.

D. Install cables so they do not bend across edges of adjacent equipment or building structure.

E. Install seismic-restraint devices using methods approved by an Independent Testing Laboratory acceptable to authorities having jurisdiction providing required submittals for component.

F. Install bushing assemblies for anchor bolts for floor-mounted equipment, arranged to provide resilient media between anchor bolt and mounting hole in concrete base.

G. Attachment to Structure: If specific attachment is not indicated, anchor bracing to structure at flanges of beams, at upper truss chords of bar joists, or at concrete members.
H. Drilled-in Anchors:

1. Identify position of reinforcing steel and other embedded items prior to drilling holes for anchors. Do not damage existing reinforcing or embedded items during coring or drilling. Notify the structural engineer if reinforcing steel or other embedded items are encountered during drilling. Locate and avoid prestressed tendons, electrical and telecommunications conduit, and gas lines.

2. Do not drill holes in concrete or masonry until concrete, mortar, or grout has achieved full design strength.

3. Wedge Anchors: Protect threads from damage during anchor installation. Heavy-duty sleeve anchors shall be installed with sleeve fully engaged in the structural element to which anchor is to be fastened.

4. Set anchors to manufacturer's recommended torque, using a torque wrench.

5. Install zinc-coated steel anchors for interior and stainless-steel anchors for exterior applications.

3.03 ACCOMMODATION OF DIFFERENTIAL SEISMIC MOTION

A. Install flexible connections in piping where they cross seismic joints, where adjacent sections or branches are supported by different structural elements, and where the connections terminate with connection to equipment that is anchored to a different structural element from the one supporting the connections as they approach equipment. Comply with requirements in Division 23 Section "Hydronic Piping" for piping flexible connections.

3.04 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. Provide evidence of recent calibration of test equipment by an Independent Testing Laboratory acceptable to Resident Engineer and Seattle Code authorities having jurisdiction.

2. Schedule test with Sound Transit through Resident Engineer, before connecting anchorage device to restrained component (unless postconnection testing has been approved), and with at least seven days' advance notice.

3. Obtain Resident Engineer's approval before transmitting test loads to structure. Provide temporary load-spreading members.

4. Test at least four of each type and size of installed anchors and fasteners selected by Resident Engineer.

5. Test to 90 percent of rated proof load of device.


7. Measure isolator deflection.

8. If a device fails test, modify all installations of same type and retest until satisfactory results are achieved.
C. Remove and replace malfunctioning units and retest as specified above.
D. Prepare test and inspection reports.

3.05 ADJUSTING

A. Adjust isolators after piping system is at operating weight.

B. Adjust limit stops on restrained spring isolators to mount equipment at normal operating height. After equipment installation is complete, adjust limit stops so they are out of contact during normal operation.

C. Adjust active height of spring isolators.

D. Adjust restraints to permit free movement of equipment within normal mode of operation.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 23 05 53
IDENTIFICATION FOR HVAC PIPING AND EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:

1. Equipment labels.
2. Warning signs and labels.
3. Pipe labels.
4. Duct labels.
5. Stencils.
6. Valve tags.
7. Warning tags.

1.02 REFERENCES

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

1. American Society of Mechanical Engineers (ASME)
   a. ASME A13.1 Scheme for Identification of Piping Systems

1.03 SUBMITTALS

A. Procedures: Section 01 33 00Submittal Procedures.
B. Product Data: For each type of product indicated.
C. Samples: For color, letter style, and graphic representation required for each identification material and device.
D. Equipment Label Schedule: Include a listing of all equipment to be labeled with the proposed content for each label.
E. Valve numbering scheme.
F. Valve Schedules: For each piping system to include in maintenance manuals.

1.04 COORDINATION

A. Coordinate installation of identifying devices with completion of covering and painting of surfaces where devices are to be applied.
B. Coordinate installation of identifying devices with locations of access panels and doors.
C. Install identifying devices before installing acoustical ceilings and similar concealment.

PART 2 - PRODUCTS

2.01 EQUIPMENT LABELS

A. Metal Labels for Equipment:

1. Material and Thickness: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.

2. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

3. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.


5. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

2.02 WARNING SIGNS AND LABELS

A. Material and Thickness: Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.


C. Background Color: Red.

D. Maximum Temperature: Able to withstand temperatures up to 160 deg F.

E. Minimum Label Size: Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. Minimum Letter Size: 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.


H. Adhesive: Contact-type permanent adhesive, compatible with label and with substrate.

I. Label Content: Include caution and warning information, plus emergency notification instructions.

2.03 PIPE LABELS

A. General Requirements for Manufactured Pipe Labels: Preprinted, color-coded, with lettering indicating service, and showing flow direction.

B. Pretensioned Pipe Labels: Precoiled, semirigid plastic formed to partially cover circumference of pipe and to attach to pipe without fasteners or adhesive.
C. **Self-Adhesive Pipe Labels:** Printed plastic with contact-type, permanent-adhesive backing.

D. **Pipe Label Contents:** Include identification of piping service using same designations or abbreviations as used on Drawings, pipe size, and an arrow indicating flow direction.

1. **Flow-Direction Arrows:** Integral with piping system service lettering to accommodate both directions, or as separate unit on each pipe label to indicate flow direction.

2. **Lettering Size:** At least 1-1/2 inches high.

### 2.04 DUCT LABELS

A. **Material and Thickness:** Multilayer, multicolor, plastic labels for mechanical engraving, 1/8 inch thick, and having predrilled holes for attachment hardware.

B. **Letter Color:** White.

C. **Background Color:** Black.

D. **Maximum Temperature:** Able to withstand temperatures up to 160 deg F.

E. **Minimum Label Size:** Length and width vary for required label content, but not less than 2-1/2 by 3/4 inch.

F. **Minimum Letter Size:** 1/4 inch for name of units if viewing distance is less than 24 inches, 1/2 inch for viewing distances up to 72 inches, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.

G. **Fasteners:** Stainless-steel self-tapping screws.

H. **Adhesive:** Contact-type permanent adhesive, compatible with label and with substrate.

I. **Duct Label Contents:** Include identification of duct service using same designations or abbreviations as used on Drawings, duct size, and an arrow indicating flow direction.

1. **Flow-Direction Arrows:** Integral with duct system service lettering to accommodate both directions, or as separate unit on each duct label to indicate flow direction.

2. **Lettering Size:** At least 1-1/2 inches high.

### 2.05 STENCILS

A. **Stencils:** Prepared with letter sizes according to ASME A13.1 for piping; minimum letter height of 1-1/4 inches for ducts; and minimum letter height of 3/4 inch for access panel and door labels, equipment labels, and similar operational instructions.

1. **Stencil Material:** Aluminum.

2. **Stencil Paint:** Exterior, gloss, alkyd enamel black unless otherwise indicated. Paint may be in pressurized spray-can form.

3. **Identification Paint:** Exterior, alkyd enamel in colors according to ASME A13.1 unless otherwise indicated.
2.06 VALVE TAGS

A. Valve Tags: Stamped or engraved with 1/4-inch letters for piping system abbreviation and 1/2-inch numbers.

1. Tag Material: Brass, 0.032-inch minimum thickness, and having predrilled or stamped holes for attachment hardware.

2. Fasteners: Brass wire-link or beaded chain; or S-hook.

B. Valve Schedules: For each piping system, on 8-1/2-by-11-inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on valve tag), location of valve (room or space), normal-operating position (open, closed, or modulating), and variations for identification. Mark valves for emergency shutoff and similar special uses.

1. Valve-tag schedule shall be included in operation and maintenance data.

2.07 WARNING TAGS

A. Warning Tags: Preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with matte finish suitable for writing.

1. Size: Approximately 4 by 7 inches.

2. Fasteners: Brass grommet and wire.

3. Nomenclature: Large-size primary caption such as "DANGER," "CAUTION," or "DO NOT OPERATE."


PART 3 - EXECUTION

3.01 PREPARATION

A. Clean piping and equipment surfaces of substances that could impair bond of identification devices, including dirt, oil, grease, release agents, and incompatible primers, paints, and encapsulants.

3.02 EQUIPMENT LABEL INSTALLATION

A. Install or permanently fasten labels on each major item of mechanical equipment.

B. Locate equipment labels where accessible and visible.

3.03 PIPE LABEL INSTALLATION

A. Piping Color-Coding: Painting of piping is specified in Division 09 Section "Interior Painting High-Performance Coatings."

B. Stenciled Pipe Label Option: Stenciled labels may be provided instead of manufactured pipe labels, at Installer's option. Install stenciled pipe labels, complying with ASME A13.1, on each piping system.

1. Identification Paint: Use for contrasting background.

C. Locate pipe labels where piping is exposed or above accessible ceilings in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior exposed locations as follows:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Where flow pattern is not obvious, mark each pipe at branch.
3. Near penetrations through walls, floors, ceilings, and inaccessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at maximum intervals of 50 feet along each run. Reduce intervals to 25 in areas of congested piping and equipment.

D. Pipe Label Color Schedule:

1. Refrigerant Piping:
   a. Background Color: Black.

3.04 DUCT LABEL INSTALLATION

A. Install plastic-laminated self-adhesive duct labels with permanent adhesive on air ducts in the following color codes:

1. Blue: For cold-air supply ducts.
2. Yellow: For hot-air supply ducts.
4. ASME A13.1 Colors and Designs: For hazardous material exhaust.

B. Stenciled Duct Label Option: Stenciled labels, showing service and flow direction, may be provided instead of plastic-laminated duct labels, at Installer's option, if lettering larger than 1 inch high is needed for proper identification because of distance from normal location of required identification.

C. Locate labels near points where ducts enter into concealed spaces and at maximum intervals of 50 feet in each space where ducts are exposed or concealed by removable ceiling system.

3.05 VALVE-TAG INSTALLATION

A. Install tags on valves and control devices in piping systems, except check valves; valves within factory-fabricated equipment units; shutoff valves; faucets; convenience and lawn-watering hose connections; and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in a valve schedule.
B. Valve-Tag Application Schedule: Tag valves according to size, shape, and color scheme and with captions similar to those indicated in the following subparagraphs:

1. Valve-Tag Size and Shape:

2. Valve-Tag Color:
   a. Refrigerant: Natural.

3. Letter Color:
   a. Refrigerant: Black.

3.06 WARNING-TAG INSTALLATION

A. Write required message on, and attach warning tags to, equipment and other items where required.

END OF SECTION
1.01 SUMMARY
   A. This Section includes specifications for testing, adjusting, and balancing (TAB) to produce design objectives for the following:
      1. Air Systems:
      2. Constant-volume air systems.
      3. HVAC equipment quantitative-performance settings.
      4. Verifying that automatic control devices are functioning properly.
      5. Reporting results of activities and procedures specified herein.

1.02 REFERENCES
   A. This Section incorporates by reference the latest revisions of the following documents.
      1. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
         a. SMACNA HVAC Systems - Testing, Adjusting, and Balancing
         b. SMACNA HVAC Systems--Duct Design
      2. Air Movement and Control Association (AMCA)
         a. AMCA 201 Fans and Systems

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Strategies and Procedures Plan: Within 30 days from Contractor's Notice to Proceed, submit six copies of TAB strategies and step-by-step procedures as specified in Article 3.02, herein. Include a complete set of report forms intended for use on this Project.
   C. Certified TAB Reports: Submit two copies of reports prepared, as specified in this Section, on approved forms certified by TAB firm including the final report.
   D. Warranties specified in this Section.

1.04 QUALITY ASSURANCE
   A. TAB Firm Qualifications: Engage a TAB firm certified by either Associated Air Balance Council (AABC) or National Environmental Balancing Bureau (NEBB).
B. Certification of TAB Reports: Certify TAB field data reports. This certification includes the following:

1. Review field data reports to validate accuracy of data and to prepare certified TAB reports.

2. Certify that TAB team complied with approved TAB plan and the procedures specified and referenced in this Specification.


1.05 PROJECT CONDITIONS

A. Full Sound Transit Occupancy: Sound Transit will occupy the site and existing building during entire TAB period. Cooperate with Sound Transit during TAB operations to minimize conflicts with Sound Transit's operations.

B. Partial Sound Transit Occupancy: Sound Transit may occupy completed areas of building before Substantial Completion. Cooperate with Sound Transit during TAB operations to minimize conflicts with Sound Transit's operations.

C. Coordination

1. Coordinate the efforts of factory-authorized service representatives for systems and equipment, HVAC controls Installers, and other mechanics to operate HVAC systems and equipment to support and assist TAB activities.

2. Perform TAB after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

1.06 WARRANTY

A. National Project Performance Guarantee: Provide a guarantee on AABC's "National Standards for Testing and Balancing Heating, Ventilating, and Air Conditioning Systems" forms stating that AABC will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee includes the following provisions:

B. Special Guarantee: Provide a guarantee on NEBB forms stating that NEBB will assist in completing requirements of the Contract Documents if TAB firm fails to comply with the Contract Documents. Guarantee shall include the following provisions:

1. The certified TAB firm has tested and balanced systems according to the Contract Documents.

2. Systems are balanced to optimum performance capabilities within design and installation limits.
PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine the Contract Documents to become familiar with Project requirements and to discover conditions in systems’ designs that may preclude proper TAB of systems and equipment.

1. Verify that balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are required by the Contract Documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.

B. Examine approved submittal data of HVAC systems and equipment.

C. Examine Project Record Documents described in Section 01 78 39, Project Record Documents.

D. Examine design data, including HVAC system descriptions, statements of design assumptions for environmental conditions and systems’ output, and statements of philosophies and assumptions about HVAC system and equipment controls.

E. Examine equipment performance data including fan and pump curves. Relate performance data to Project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, “Fans and Systems,” Sections 7 through 10; or in SMACNA’s “HVAC Systems--Duct Design,” Sections 5 and 6 in this Contract Specification. Compare this data with the design data and installed conditions.

F. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual Sections have been performed.

G. Examine system and equipment test reports.

H. Examine HVAC system and equipment installations to verify that indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices, balancing valves and fittings, and manual volume dampers, are properly installed, and that their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.

I. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.

J. Examine HVAC equipment to ensure that clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.
K. Examine terminal units, such as variable-air-volume boxes, to verify that they are accessible and their controls are connected and functioning.

L. Examine plenum ceilings used for supply air to verify that they are airtight. Verify that pipe penetrations and other holes are sealed.

M. Examine strainers for clean screens and proper perforations.

N. Examine heat-transfer coils for correct piping connections and for clean and straight fins.

O. Examine system pumps to ensure absence of entrained air in the suction piping.

P. Examine equipment for installation and for properly operating safety interlocks and controls.

Q. Examine automatic temperature system components to verify the following:
   1. Dampers, valves, and other controlled devices are operated by the intended controller.
   2. Dampers and valves are in the position indicated by the controller.
   3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions. This includes dampers in multizone units, mixing boxes, and variable-air-volume terminals.
   4. Automatic modulating and shutoff valves, including two-way valves and three-way mixing and diverting valves, are properly connected.
   5. Thermostats and humidistsats are located to avoid adverse effects of sunlight, drafts, and cold walls.
   6. Sensors are located to sense only the intended conditions.
   7. Sequence of operation for control modes is according to the Contract Documents.
   8. Controller set points are set at indicated values.
   9. Interlocked systems are operating.
   10. Changeover from heating to cooling mode occurs according to indicated values.

R. Report deficiencies discovered before and during performance of TAB procedures. Observe and record system reactions to changes in conditions. Record default set points if different from indicated values.

3.02 PREPARATION

A. Prepare a TAB plan that includes strategies and step-by-step procedures.

B. Complete system readiness checks and prepare system readiness reports. Verify the following:
   1. Permanent electrical power wiring is complete.
   2. Automatic temperature-control systems are operational.
   3. Equipment and duct access doors are securely closed.
4. Balance, smoke, and fire dampers are open.

5. Isolating and balancing valves are open and control valves are operational.

6. Ceilings are installed in critical areas where air-pattern adjustments are required and access to balancing devices is provided.

7. Windows and doors can be closed so indicated conditions for system operations can be met.

3.03 FIELD QUALITY CONTROL

A. Tolerances

1. Set HVAC system airflow and water flow rates within the following tolerances:
   a. Supply, Return, and Exhaust Fans and Equipment with Fans: Plus 5 to plus 10 percent.
   b. Air Outlets and Inlets: 0 to minus 10 percent.
   c. Heating-Water Flow Rate: 0 to minus 10 percent.
   d. Cooling-Water Flow Rate: 0 to minus 5 percent.

B. General Procedures for Testing and Balancing

1. Perform testing and balancing procedures on each system according to the procedures contained in SMACNA's "HVAC Systems - Testing, Adjusting, and Balancing" and this Section.

2. Cut insulation, ducts, pipes, and equipment cabinets for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, close probe holes and patch insulation with new materials identical to those removed. Restore vapor barrier and finish according to insulation Specifications for this Project.

3. Mark equipment and balancing device settings with paint or other suitable, permanent identification material, including damper-control positions, valve position indicators, fan-speed-control levers, and similar controls and devices, to show final settings.

C. General Procedures for Balancing Air Systems

1. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.

2. Prepare schematic diagrams of systems' "as-built" duct layouts.

3. Determine the best locations in main and branch ducts for accurate duct airflow measurements.

4. Check airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.

5. Locate start-stop and disconnect switches, electrical interlocks, and motor starters.
6. Verify that motor starters are equipped with properly sized thermal protection.
7. Check dampers for proper position to achieve desired airflow path.
8. Check for airflow blockages.
9. Check condensate drains for proper connections and functioning.
10. Check for proper sealing of air-handling unit components.
11. Check for proper sealing of air duct system.

D. Procedures for Constant-Volume Air Systems

1. Adjust fans to deliver total indicated airflows within the maximum allowable fan speed listed by fan manufacturer.
   a. Measure fan static pressures to determine actual static pressure as follows:
      1) Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
      2) Measure static pressure directly at the fan outlet or through the flexible connection.
      3) Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
      4) Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.
   b. Measure static pressure across each component that makes up an air-handling unit, rooftop unit, and other air-handling and treating equipment.
      1) Simulate dirty filter operation and record the point at which maintenance personnel must change filters.
   c. Measure static pressures entering and leaving other devices such as sound traps, heat recovery equipment, and air washers, under final balanced conditions.
   d. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
   e. Obtain approval from Resident Engineer for adjustment of fan speed higher or lower than indicated speed. Make required adjustments to pulley sizes, motor sizes, and electrical connections to accommodate fan-speed changes.
   f. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors.
Modulate dampers and measure fan-motor amperage to ensure that no overload will occur. Measure amperage in full cooling, full heating, economizer, and all other operating modes to determine the maximum required brake horsepower.

2. Adjust volume dampers for main duct, submain ducts, and major branch ducts to indicated airflows within specified tolerances.
   a. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.
      1) Where sufficient space in submain and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.
   b. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submain and branch ducts to indicated airflows within specified tolerances.

3. Measure terminal outlets and inlets without making adjustments.
   a. Measure terminal outlets using a direct-reading hood or outlet manufacturer's written instructions and calculating factors.

4. Adjust terminal outlets and inlets for each space to indicated airflows within specified tolerances of indicated values. Make adjustments using volume dampers rather than extractors and the dampers at air terminals.
   a. Adjust each outlet in same room or space to within specified tolerances of indicated quantities without generating noise levels above the limitations prescribed by the Contract Documents.
   b. Adjust patterns of adjustable outlets for proper distribution without drafts.

E. Procedures for Motors

1. Motors, 1/2 HP and Larger: Test at final balanced conditions and record the following data:
   a. Manufacturer, model, and serial numbers.
   b. Motor horsepower rating.
   c. Motor rpm.
   d. Efficiency rating.
   e. Nameplate and measured voltage, each phase.
   f. Nameplate and measured amperage, each phase.
   g. Starter thermal-protection-element rating.

2. Motors Driven by Variable-Frequency Controllers: Test for proper operation at speeds varying from minimum to maximum. Test the manual bypass for the
controller to prove proper operation. Record observations, including controller manufacturer, model and serial numbers, and nameplate data.

F. Procedures for Condensing Units

1. Verify proper rotation of fans.
2. Measure entering- and leaving-air temperatures.
3. Record compressor data.

G. Procedures for Temperature Measurements

1. During TAB, report the need for adjustment in temperature regulation within the automatic temperature-control system.
2. Measure indoor wet- and dry-bulb temperatures every other hour for a period of two successive eight-hour days, in each separately controlled zone, to prove correctness of final temperature settings. Measure when the building or zone is occupied.
3. Measure outside-air, wet- and dry-bulb temperatures.

H. Temperature-Control Verification

1. Verify that controllers are calibrated and commissioned.
2. Check transmitter and controller locations and note conditions that would adversely affect control functions.
3. Record controller settings and note variances between set points and actual measurements.
4. Check the operation of limiting controllers (i.e., high- and low-temperature controllers).
5. Check free travel and proper operation of control devices such as damper and valve operators.
6. Check the sequence of operation of control devices. Note air pressures and device positions and correlate with airflow and water flow measurements. Note the speed of response to input changes.
7. Check the interaction of electrically operated switch transducers.
8. Check the interaction of interlock and lockout systems.
9. Check main control supply-air pressure and observe compressor and dryer operations.
10. Record voltages of power supply and controller output. Determine whether the system operates on a grounded or nongrounded power supply.
11. Note operation of electric actuators using spring return for proper fail-safe operations.

I. Additional Tests
1. Within 90 days of completing TAB, perform additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

2. Seasonal Periods: If initial TAB procedures were not performed during near-peak summer and winter conditions, perform additional testing, inspecting, and adjusting during near-peak summer and winter conditions.

3.04 FINAL REPORT

A. General: Typewritten, or computer printout in letter-quality font, on standard bond paper, in three-ring binder, tabulated and divided into sections by tested and balanced systems.

B. Include a certification sheet in front of binder signed and sealed by the certified testing and balancing engineer.

1. Include a list of instruments used for procedures, along with proof of calibration.

C. Final Report Contents: In addition to certified field report data, include the following:

1. Pump curves.
2. Fan curves.
3. Manufacturers' test data.
4. Field test reports prepared by system and equipment Installers.
5. Other information relative to equipment performance, but do not include Shop Drawings and Product Data.

D. General Report Data: In addition to form titles and entries, include the following data in the final report, as applicable:

1. Title page.
2. Name and address of TAB firm.
3. Project name.
4. Project location.
5. Architect's name and address.
6. Engineer's name and address.
7. Contractor's name and address.
9. Signature of TAB firm who certifies the report.
10. Table of Contents with the total number of pages defined for each section of the report. Number each page in the report.
11. Summary of contents including the following:
   a. Indicated versus final performance.
b. Notable characteristics of systems.

c. Description of system operation sequence if it varies from the Contract Documents.

12. Nomenclature sheets for each item of equipment.

13. Notes to explain why certain final data in the body of reports varies from indicated values.

14. Test conditions for fans and pump performance forms including the following:
   a. Settings for outside-, return-, and exhaust-air dampers.
   b. Conditions of filters.
   c. Cooling coil, wet- and dry-bulb conditions.
   d. Face and bypass damper settings at coils.
   e. Fan drive settings including settings and percentage of maximum pitch diameter.
   f. Inlet vane settings for variable-air-volume systems.
   g. Settings for supply-air, static-pressure controller.
   h. Other system operating conditions that affect performance.

E. System Diagrams: Include schematic layouts of air systems. Present each system with single-line diagram and include the following:

1. Quantities of outside, supply, return, and exhaust airflows.
2. Duct, outlet, and inlet sizes.
3. Pipe and valve sizes and locations.
5. Position of balancing devices.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes specifications for the following:

1. Insulation Materials:
   a. Cellular glass.
   b. Mineral fiber.

2. Fire-rated insulation systems.

3. Insulating cements.

4. Adhesives.

5. Mastics.


7. Factory-applied jackets.


10. Tapes.

11. Securements.

12. Corner angles.

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 07 84 00, Firestopping.

2. Section 22 07 00, Plumbing Insulation.

3. Section 23 31 13, Metal Ducts.

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)

b. ASTM B 209 Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate

c. ASTM C 921 Standard Practice for Determining the Properties of Jacketing Materials for Thermal Insulation

d. ASTM E 84 Standard Test Method for Surface Burning Characteristics of Building Materials

e. ASTM C 871 Standard Test Methods for Chemical Analysis of Thermal Insulation Materials for Leachable Chloride, Fluoride, Silicate, and Sodium Ions

f. ASTM C 795 Standard Specification for Thermal Insulation for Use in Contact with Austenitic Stainless Steel

g. ASTM C 552 Standard Specification for Cellular Glass Thermal Insulation

h. ASTM C 450 Standard Practice for Fabrication of Thermal Insulating Fitting Covers for NPS Piping, and Vessel Lagging

i. ASTM C 585 Standard Practice for Inner and Outer Diameters of Rigid Thermal Insulation for Nominal Sizes of Pipe and Tubing (NPS System)

j. ASTM C 534 Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form

k. ASTM C 553 Standard Specification for Mineral Fiber Blanket Thermal Insulation for commercial and Industrial Applications

l. ASTM C 1290 Standard Specification for Flexible Fibrous Glass Blanket Insulation Used to Externally Insulate HVAC Ducts

m. ASTM C 612 Standard Specification for Mineral Fiber Block and Board Thermal Insulation

n. ASTM C 547 Standard Specification for Mineral Fiber Pipe Insulation

o. ASTM C 1393 Standard Specification for Perpendicularly Oriented Mineral Fiber Roll and Sheet Thermal Insulation for Pipes and Tanks


q. ASTM E 96 Standard Testing Methods for Water Vapor Transmission of Materials

r. ASTM D 1644 Standard Test Method for Nonvolatile Content of Varnishes

s. ASTM F 1249 Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor
1. ASTM C 1136 Standard Specification for Flexible, Low Permeance Vapor Retarders for Thermal Insulation

2. Military Specifications (MIL)
   a. MIL-A-24179A Adhesive, Flexible Unicellular Thermal Insulation
   b. MIL-A-3316C Adhesives, Fire-Resistant, Thermal Insulation
   c. MIL-C-19565C Coating Compounds, Thermal Insulation, Fire-and Water-Resistant, Vapor Barrier

3. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)

1.03 SUBMITTALS

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

B. Product Data: For each type of product indicated.

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 pipe expansion joints for each type of insulation.
   4. Detail insulation application at elbows, fittings, flanges, valves, and specialties for each type of insulation.
   5. Detail removable insulation at piping specialties, equipment connections, and access panels.
   6. Detail application of field-applied jackets.
   7. Detail application at linkages of control devices.
   8. Detail field application for each equipment type.

D. Field quality-control reports.

1.04 QUALITY ASSURANCE

A. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics indicated, as determined by testing identical products per American Society for Testing and Materials ASTM E 84, by an Independent Testing Laboratory acceptable to authorities having jurisdiction. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing and inspecting agency.

1. Insulation Installed Indoors: Flame-spread index of 25 or less, and smoke-developed index of 50 or less.
2. Insulation Installed Outdoors: Flame-spread index of 75 or less, and smoke-developed index of 150 or less.

PART 2 - PRODUCTS

2.01 INSULATION MATERIALS

A. Comply with requirements of Part, Execution, herein, for locations where insulating materials shall be applied.

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

C. Products that come in contact with stainless steel shall have a leachable chloride content of less than 50 ppm when tested according to ASTM C 871.

D. Insulation materials for use on austenitic stainless steel shall be qualified as acceptable according to ASTM C 795.

E. Foam insulation materials shall not use CFC or HCFC blowing agents in the manufacturing process.

F. Cellular Glass: Inorganic, incombustible, foamed or cellulated glass with annealed, rigid, hermetically sealed cells. Factory-applied jacket requirements are specified in Article 2.07, herein.

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. Cell-U-Foam Corporation; Ultra-CUF.
   b. Pittsburgh Corning Corporation; Foamglas Super K.

2. Block Insulation: ASTM C 552, Type I.

3. Special-Shaped Insulation: ASTM C 552, Type III.

4. Board Insulation: ASTM C 552, Type IV.

5. Preformed Pipe Insulation without Jacket: Comply with ASTM C 552, Type II, Class 1.


7. Factory fabricate shapes according to ASTM C 450 and ASTM C 585.

G. Flexible Elastomeric: Closed-cell, sponge- or expanded-rubber materials. Comply with ASTM C 534, Type I for tubular materials and Type II for sheet materials.

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. Aeroflex USA Inc.; Aerocel.
   b. Armacell LLC; AP Armaflex.
   c. RBX Corporation; Insul-Sheet 1800 and Insul-Tube 180.
H. Mineral-Fiber Blanket Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 553, Type II and ASTM C 1290, Type III with factory-applied FSK jacket. Factory-applied jacket requirements are specified in Article 2.07, Factory Applied Jackets.

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. CertainTeed Corp.; Duct Wrap.
   b. Johns Manville; Microlite.
   c. Knauf Insulation; Duct Wrap.
   d. Manson Insulation Inc.; Alley Wrap.
   e. Owens Corning; All-Service Duct Wrap.

I. Mineral-Fiber Board Insulation: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IA or Type IB. For duct and plenum applications, provide insulation with factory-applied FSK jacket. For equipment applications, provide insulation with factory-applied FSK jacket. Factory-applied jacket requirements are specified in Article 2.07, Factory Applied Jackets.

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. CertainTeed Corp.; Commercial Board.
   b. Fibrex Insulations Inc.; FBX.
   c. Johns Manville; 800 Series Spin-Glas.
   d. Knauf Insulation; Insulation Board.
   e. Manson Insulation Inc.; AK Board.
   f. Owens Corning; Fiberglas 700 Series.

J. Mineral-Fiber, Preformed Pipe Insulation:

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. Fibrex Insulations Inc.; Coreplus 1200.
   b. Johns Manville; Micro-Lok.
   c. Knauf Insulation; 1000 Pipe Insulation.
   d. Manson Insulation Inc.; Alley-K.
   e. Owens Corning; Fiberglas Pipe Insulation.
   f. For operating temperatures higher than 850 degrees F, delete first subparagraph below and retain second subparagraph. ASJ requires field-applied adhesive and staples. ASJ with SSL does not require field-applied adhesive and staples, resulting in reduced installation labor.
2. Type I, 850 degrees F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type I, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in Article 2.07, herein.

3. Type II, 1200 degrees F Materials: Mineral or glass fibers bonded with a thermosetting resin. Comply with ASTM C 547, Type II, Grade A, with factory-applied ASJ-SSL. Factory-applied jacket requirements are specified in Article 2.07, herein.

K. Mineral-Fiber, Pipe Insulation Wicking System: Preformed pipe insulation complying with ASTM C 547, Type I, Grade A, with absorbent cloth factory applied to the entire inside surface of preformed pipe insulation and extended through the longitudinal joint to outside surface of insulation under insulation jacket. Factory apply a white, polymer, vapor-retarder jacket with self-sealing adhesive tape seam and evaporation holes running continuously along the longitudinal seam, exposing the absorbent cloth.

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. Knauf Insulation; Permawick Pipe Insulation.
   b. Owens Corning; VaporWick Pipe Insulation.

L. Mineral-Fiber, Pipe and Tank Insulation: Mineral or glass fibers bonded with a thermosetting resin. Semirigid board material with factory-applied FSK jacket complying with ASTM C 1393, Type II or Type IIIA Category 2, or with properties similar to ASTM C 612, Type IB. Nominal density is 2.5 lb/cu. ft. or more. Thermal conductivity (k-value) at 100 degrees F is 0.29 Btu x in./h x sq. ft. x degrees F or less. Factory-applied jacket requirements are specified in Article 2.07, herein.

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. CertainTeed Corp.; CrimpWrap.
   b. Johns Manville; MicroFlex.
   c. Knauf Insulation; Pipe and Tank Insulation.
   d. Manson Insulation Inc.; AK Flex.
   e. Owens Corning; Fiberglas Pipe and Tank Insulation.

2.02 FIRE-RATED INSULATION SYSTEMS

A. Fire-Rated Blanket: High-temperature, flexible, blanket insulation with FSK jacket that is tested and certified to provide a two-hour fire rating by a NRTL acceptable to authority having jurisdiction.

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. CertainTeed Corp.; FlameChek.
   b. Johns Manville; Firetemp Wrap.
d. Thermal Ceramics; FireMaster Duct Wrap.

e. 3M; Fire Barrier Wrap Products.

f. Unifrax Corporation; FyreWrap.

g. Vesuvius; PYROSCAT FP FASTR Duct Wrap.

2.03 INSULATING CEMENTS

A. Mineral-Fiber, Hydraulic-Setting Insulating and Finishing Cement: Comply with ASTM C 449/C 449M.

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. Insulco, Division of MFS, Inc.; SmoothKote.


   c. Rock Wool Manufacturing Company; Delta One Shot.

2.04 ADHESIVES

A. Materials shall be compatible with insulation materials, jackets, and substrates and for bonding insulation to itself and to surfaces to be insulated, unless otherwise indicated.

B. Cellular-Glass, Phenolic, Polyisocyanurate, and Polystyrene Adhesive: Solvent-based resin adhesive, with a service temperature range of minus 75 to plus 300 degrees F.

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. Childers Products, Division of ITW; CP-96.


C. Flexible Elastomeric and Polyolefin Adhesive: Comply with MIL-A-24179A, Type II, Class I.

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. Aeroflex USA Inc.; Aeroseal.

   b. Armacell LCC; 520 Adhesive.

   c. Foster Products Corporation, H. B. Fuller Company; 85-75.

   d. RBX Corporation; Rubatex Contact Adhesive.

D. Mineral-Fiber Adhesive: Comply with MIL-A-3316C, Class 2, Grade A.

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. Childers Products, Division of ITW; CP-82.

c. ITW TACC, Division of Illinois Tool Works; S-90/80.

d. Marathon Industries, Inc.; 225.

e. Mon-Eco Industries, Inc.; 22-25.


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. Childers Products, Division of ITW; CP-82.
   
   
   c. ITW TACC, Division of Illinois Tool Works; S-90/80.
   
   d. Marathon Industries, Inc.; 225.
   
   e. Mon-Eco Industries, Inc.; 22-25.

2.05 MASTICS

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

B. Vapor-Barrier Mastic: Water based; suitable for indoor and outdoor use on below ambient services.

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. Childers Products, Division of ITW; CP-35.
   
   b. Foster Products Corporation, H. B. Fuller Company; 30-90.
   
   c. ITW TACC, Division of Illinois Tool Works; CB-50.
   
   d. Marathon Industries, Inc.; 590.
   
   e. Mon-Eco Industries, Inc.; 55-40.
   
   f. Vimasco Corporation; 749.

2. Water-Vapor Permeance: ASTM E 96, Procedure B, 0.013 perm at 43-mil dry film thickness.

3. Service Temperature Range: Minus 20 to plus 180 degrees F.


C. Breather Mastic: Water based; suitable for indoor and outdoor use on above ambient services.

1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
2.06 SEALANTS

A. Joint Sealants:

1. Joint Sealants for Cellular-Glass Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Products, Division of ITW; CP-76.
   b. Foster Products Corporation, H. B. Fuller Company; 30-45.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Pittsburgh Corning Corporation; Pittseal 444.
   f. Vimasco Corporation; 750.

2. Joint Sealants for Polystyrene Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
   a. Childers Products, Division of ITW; CP-70.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Vimasco Corporation; 750.

3. Materials shall be compatible with insulation materials, jackets, and substrates.

4. Permanently flexible, elastomeric sealant.
5. Service Temperature Range: Minus 100 to plus 300 degrees F.
6. Color: White or gray.

B. FSK and Metal Jacket Flashing Sealants:

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. Childers Products, Division of ITW; CP-76-8.
   b. Foster Products Corporation, H. B. Fuller Company; 95-44.
   c. Marathon Industries, Inc.; 405.
   d. Mon-Eco Industries, Inc.; 44-05.
   e. Vimasco Corporation; 750.

2. Materials shall be compatible with insulation materials, jackets, and substrates.

3. Fire- and water-resistant, flexible, elastomeric sealant.

4. Service Temperature Range: Minus 40 to plus 250 degrees F.

5. Color: Aluminum.

C. ASJ Flashing Sealants, and Vinyl, PVDC, and PVC Jacket Flashing Sealants:

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. Childers Products, Division of ITW; CP-76.

2. Materials shall be compatible with insulation materials, jackets, and substrates.

3. Fire- and water-resistant, flexible, elastomeric sealant.

4. Service Temperature Range: Minus 40 to plus 250 degrees F.


2.07 FACTORY-APPLIED JACKETS

A. Insulation system schedules indicate factory-applied jackets on various applications. When factory-applied jackets are indicated, comply with the following:

1. ASJ: White, kraft-paper, fiberglass-reinforced scrim with aluminum-foil backing; complying with ASTM C 1136, Type I.

2. ASJ-SSL: ASJ with self-sealing, pressure-sensitive, acrylic-based adhesive covered by a removable protective strip; complying with ASTM C 1136, Type I.

3. FSK Jacket: Aluminum-foil, fiberglass-reinforced scrim with kraft-paper backing; complying with ASTM C 1136, Type II.

4. FSP Jacket: Aluminum-foil, fiberglass-reinforced scrim with polyethylene backing; complying with ASTM C 1136, Type II.
2.08 FIELD-APPLIED FABRIC-REINFORCING MESH

A. Woven Polyester Fabric: Approximately 1 oz./sq. yd. with a thread count of 10 strands by 10 strands/sq. inch, in a Leno weave, for duct, equipment, and pipe.

   1. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
     b. Vimasco Corporation; Elastafab 894.

2.09 FIELD-APPLIED JACKETS

A. Field-applied jackets shall comply with ASTM C 921, Type I, unless otherwise indicated.

B. FSK Jacket: Aluminum-foil-face, fiberglass-reinforced scrim with kraft-paper backing.

C. Aluminum Jacket: Comply with ASTM B 209, Alloy 3003, 3005, 3105 or 5005, Temper H-14.

   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. Childers Products, Division of ITW; Metal Jacketing Systems.
     b. PABCO Metals Corporation; Surefit.
     c. RPR Products, Inc.; Insul-Mate.

   2. Sheet and roll stock ready for shop or field sizing.

   3. Finish and thickness are indicated in field-applied jacket schedules.


   5. Moisture Barrier for Outdoor Applications: 3-mil-thick, heat-bonded polyethylene and kraft paper.

   6. Factory-Fabricated Fitting Covers:
     a. Same material, finish, and thickness as jacket.
     b. Preformed 2-piece or gore, 45- and 90-degree, short- and long-radius elbows.
     c. Tee covers.
     d. Flange and union covers.
     e. End caps.
     f. Beveled collars.
     g. Valve covers.
     h. Field fabricate fitting covers only if factory-fabricated fitting covers are not available.
D. Self-Adhesive Outdoor Jacket: 60-mil thick, laminated vapor barrier and waterproofing membrane for installation over insulation located aboveground outdoors; consisting of a rubberized bituminous resin on a crosslaminated polyethylene film covered with white aluminum-foil facing.

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. Polyguard; Alumaguard 60.

2.10 TAPES

A. ASJ Tape: White vapor-retarder tape matching factory-applied jacket with acrylic adhesive, complying with ASTM C 1136.

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. FSK Tape: Foil-face, vapor-retarder tape matching factory-applied jacket with acrylic adhesive; complying with ASTM C 1136.

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 0827.
   b. Compac Corp.; 110 and 111.
   c. Ideal Tape Co., Inc., an American Biltrite Company; 491 AWF FSK.
   d. Venture Tape; 1525 CW, 1528 CW, and 1528 CW/SQ.

2. Width: 3 inches.
3. Thickness: 6.5 mils.
5. Elongation: 2 percent.
6. Tensile Strength: 40 lbf/inch in width.

7. FSK Tape Disks and Squares: Precut disks or squares of FSK tape.

C. 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.

2.11 SECUREMENTS

A. Aluminum Bands: ASTM B 209, Alloy 3003, 3005, 3105, or 5005; Temper H-14, 0.020 inch thick, 3/4 inch wide with wing or closed seal.

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. Childers Products; Bands.
   b. PABCO Metals Corporation; Bands.
   c. RPR Products, Inc.; Bands.

B. Insulation Pins and Hangers:

1. Metal, Adhesively Attached, Perforated-Base Insulation Hangers: Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:
   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:
      1) AGM Industries, Inc.; Tactoo Insul-Hangers, Series T.
      2) GEMCO; Perforated Base.
      3) Midwest Fasteners, Inc.; Spindle.
b. **Baseplate:** Perforated, galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.

c. **Spindle:** Stainless steel, fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.

d. **Adhesive:** Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

2. **Nonmetal, Adhesively Attached, Perforated-Base Insulation Hangers:** Baseplate fastened to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

   a. **Products:** Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

      1) GEMCO; Nylon Hangers.

      2) Midwest Fasteners, Inc.; Nylon Insulation Hangers.

   b. **Baseplate:** Perforated, nylon sheet, 0.030 inch thick by 1-1/2 inches in diameter.

   c. **Spindle:** Nylon, 0.106-inch-diameter shank, length to suit depth of insulation indicated, up to 2-1/2 inches.

   d. **Adhesive:** Recommended by hanger manufacturer. Product with demonstrated capability to bond insulation hanger securely to substrates indicated without damaging insulation, hangers, and substrates.

3. **Self-Sticking-Base Insulation Hangers:** Baseplate welded to projecting spindle that is capable of holding insulation, of thickness indicated, securely in position indicated when self-locking washer is in place. Comply with the following requirements:

   a. **Products:** Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

      1) AGM Industries, Inc.; Tactoo Insul-Hangers, Series TSA.

      2) GEMCO; Press and Peel.

      3) Midwest Fasteners, Inc.; Self Stick.

   b. **Baseplate:** Galvanized carbon-steel sheet, 0.030 inch thick by 2 inches square.

   c. **Spindle:** Stainless steel, fully annealed, 0.106-inch-diameter shank, length to suit depth of insulation indicated.

   d. **Adhesive-backed base with a peel-off protective cover.**
4. Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick, stainless-steel sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

      1) AGM Industries, Inc.; RC-150.
      2) GEMCO; R-150.
      3) Midwest Fasteners, Inc.; WA-150.
      4) Nelson Stud Welding; Speed Clips.

   b. Protect ends with capped self-locking washers incorporating a spring steel insert to ensure permanent retention of cap in exposed locations.

5. Nonmetal Insulation-Retaining Washers: Self-locking washers formed from 0.016-inch-thick nylon sheet, with beveled edge sized as required to hold insulation securely in place but not less than 1-1/2 inches in diameter.

   a. Products: Subject to compliance with requirements, available products that may be incorporated into the Work include, but are not limited to, the following:

      1) GEMCO.
      2) Midwest Fasteners, Inc.

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

D. Wire: 0.080-inch nickel-copper alloy.

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. Childers Products.
   c. PABCO Metals Corporation.
   d. RPR Products, Inc.

2.12 CORNER ANGLES

A. PVC Corner Angles: 30 mils thick, minimum 1 by 1 inch, PVC according to ASTM D 1784, Class 16354-C. White or color-coded to match adjacent surface.

B. Aluminum Corner Angles: 0.040 inch thick, minimum 1 by 1 inch, aluminum according to ASTM B 209, Alloy 3003, 3005, 3105 or 5005; Temper H-14.
PART 3 - EXECUTION

3.01 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 will be in contact with stainless-steel surfaces, use demineralized water.

3.02 GENERAL INSTALLATION REQUIREMENTS

A. Install insulation materials, accessories, and finishes with smooth, straight, and even surfaces; free of voids throughout the length of equipment, ducts and fittings, 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, duct system, and pipe system as specified in insulation system schedules.

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. Install multiple layers of insulation with longitudinal and end seams staggered.

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

G. Keep insulation materials dry during application and finishing.

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

I. Install insulation with least number of joints practical.

J. Where vapor barrier is indicated, seal joints, seams, and penetrations in insulation at hangers, supports, anchors, and other projections with vapor-barrier mastic.

   1. Install insulation continuously through hangers and around anchor attachments.

   2. For insulation application where vapor barriers are indicated, extend insulation on anchor legs from point of attachment to supported item to point of attachment to structure. Taper and seal ends at attachment to structure with vapor-barrier mastic.

   3. Install insert materials and install insulation to tightly join the insert. Seal insulation to insulation inserts with adhesive or sealing compound recommended by insulation material manufacturer.
4. Cover inserts with jacket material matching adjacent pipe insulation. Install shields over jacket, arranged to protect jacket from tear or puncture by hanger, support, and shield.

K. Apply adhesives, mastics, and sealants at manufacturer’s recommended coverage rate and wet and dry film thicknesses.

L. 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 4 inches o.c.
   4. For below ambient services, apply vapor-barrier mastic over staples.
   5. Cover joints and seams with tape as recommended by insulation material manufacturer to maintain vapor seal.
   6. Where vapor barriers are indicated, apply vapor-barrier mastic on seams and joints and at ends adjacent to duct and pipe flanges and fittings.

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

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

O. 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.

P. For above ambient services, do not install insulation to the following:
   1. Vibration-control devices.
   2. Testing agency labels and stamps.
   3. Nameplates and data plates.
   5. Handholes.
   6. Cleanouts.

3.03 PENETRATIONS

A. Insulation Installation at Roof Penetrations: Install insulation continuously through roof penetrations.
   1. Seal penetrations with flashing sealant.
2. For applications requiring only indoor insulation, terminate insulation above roof surface and seal with joint sealant. For applications requiring indoor and outdoor insulation, install insulation for outdoor applications tightly joined to indoor insulation ends. Seal joint with joint sealant.

3. Extend jacket of outdoor insulation outside roof flashing at least 2 inches below top of roof flashing.

4. Seal jacket to roof flashing with flashing sealant.

B. Insulation Installation at Underground Exterior Wall Penetrations: Terminate insulation flush with sleeve seal. Seal terminations with flashing sealant.

C. Insulation Installation at Interior Wall and Partition Penetrations (That Are Not Fire Rated): Install insulation continuously through walls and partitions.

D. Insulation Installation at Fire-Rated Wall and Partition Penetrations: Install insulation continuously through penetrations of fire-rated walls and partitions. Terminate insulation at fire damper sleeves for fire-rated wall and partition penetrations. Externally insulate damper sleeves to match adjacent insulation and overlap duct insulation at least 2 inches.

   1. Comply with requirements in Section 07 84 00, Firestopping.

E. Insulation Installation at Floor Penetrations:

   1. Duct: Install insulation continuously through floor penetrations that are not fire rated. For penetrations through fire-rated assemblies, terminate insulation at fire damper sleeves and externally insulate damper sleeve beyond floor to match adjacent duct insulation. Overlap damper sleeve and duct insulation at least 2 inches.

   2. Pipe: Install insulation continuously through floor penetrations.

   3. Seal penetrations through fire-rated assemblies: Comply with requirements of Section 07 84 00, Firestopping.

3.04 EQUIPMENT, TANK, AND VESSEL INSULATION INSTALLATION

A. Mineral Fiber, Pipe and Tank Insulation Installation for Tanks and Vessels: Secure insulation with adhesive and anchor pins and speed washers.

   1. Apply adhesives according to manufacturer’s recommended coverage rates per unit area, for percent coverage of tank and vessel surfaces.

   2. Groove and score insulation materials to fit as closely as possible to equipment, including contours. Bevel insulation edges for cylindrical surfaces for tight joints. Stagger end joints.

   3. Protect exposed corners with secured corner angles.

   4. Install adhesively attached or self-sticking insulation hangers and speed washers on sides of tanks and vessels as follows:

      a. Do not weld anchor pins to ASME-labeled pressure vessels.

      b. Select insulation hangers and adhesive that are compatible with service temperature and with substrate.
c. On tanks and vessels, maximum anchor-pin spacing is 3 inches from insulation end joints, and 16 inches o.c. in both directions.

d. Do not overcompress insulation during installation.

e. Cut and miter insulation segments to fit curved sides and domed heads of tanks and vessels.

f. Impale insulation over anchor pins and attach speed washers.

g. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

5. Secure each layer of insulation with stainless-steel or aluminum bands. Select band material compatible with insulation materials.

6. Where insulation hangers on equipment and vessels are not permitted or practical and where insulation support rings are not provided, install a girdle network for securing insulation. Stretch prestressed aircraft cable around the diameter of vessel and make taut with clamps, turnbuckles, or breather springs. Place one circumferential girdle around equipment approximately 6 inches from each end. Install wire or cable between two circumferential girdles 12 inches o.c. Install a wire ring around each end and around outer periphery of center openings, and stretch prestressed aircraft cable radially from the wire ring to nearest circumferential girdle. Install additional circumferential girdles along the body of equipment or tank at a minimum spacing of 48 inches o.c. Use this network for securing insulation with tie wire or bands.

7. Stagger joints between insulation layers at least 3 inches.

8. Install insulation in removable segments on equipment access doors, manholes, handholes, and other elements that require frequent removal for service and inspection.

9. Bevel and seal insulation ends around manholes, handholes, ASME stamps, and nameplates.

10. For equipment with surface temperatures below ambient, apply mastic to open ends, joints, seams, breaks, and punctures in insulation.

B. Flexible Elastomeric Thermal Insulation Installation for Tanks and Vessels: Install insulation over entire surface of tanks and vessels.

1. Apply 100 percent coverage of adhesive to surface with manufacturer's recommended adhesive.

2. Seal longitudinal seams and end joints.

C. Insulation Installation on Pumps:

1. Fabricate metal boxes lined with insulation. Fit boxes around pumps and coincide box joints with splits in pump casings. Fabricate joints with outward bolted flanges. Bolt flanges on 6-inch centers, starting at corners. Install 3/8-inch diameter fasteners with wing nuts. Alternatively, secure the box sections together using a latching mechanism.

2. Fabricate boxes from aluminum, at least 0.050 inch thick.
3. For below ambient services, install a vapor barrier at seams, joints, and penetrations. Seal between flanges with replaceable gasket material to form a vapor barrier.

3.05 GENERAL PIPE INSULATION INSTALLATION

A. Requirements in this article generally apply to all insulation materials except where more specific requirements are specified in various pipe insulation material installation articles.

B. Insulation Installation on Fittings, Valves, Strainers, Flanges, and Unions:

1. Install insulation over fittings, valves, strainers, flanges, unions, and other specialties with continuous thermal and vapor-retarder integrity, unless otherwise indicated.

2. Insulate pipe elbows using preformed fitting insulation or mitered fittings made from same material and density as adjacent pipe insulation. Each piece shall be butted tightly against adjoining piece and bonded with adhesive. Fill joints, seams, voids, and irregular surfaces with insulating cement finished to a smooth, hard, and uniform contour that is uniform with adjoining pipe insulation.

3. Insulate tee fittings with preformed fitting insulation or sectional pipe insulation of same material and thickness as used for adjacent pipe. Cut sectional pipe insulation to fit. Butt each section closely to the next and hold in place with tie wire. Bond pieces with adhesive.

4. Insulate valves using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. For valves, insulate up to and including the bonnets, valve stuffing-box studs, bolts, and nuts. Fill joints, seams, and irregular surfaces with insulating cement.

5. Insulate strainers using preformed fitting insulation or sectional pipe insulation of same material, density, and thickness as used for adjacent pipe. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker. Fill joints, seams, and irregular surfaces with insulating cement. Insulate strainers so strainer basket flange or plug can be easily removed and replaced without damaging the insulation and jacket. Provide a removable reusable insulation cover. For below ambient services, provide a design that maintains vapor barrier.

6. Insulate flanges and unions using a section of oversized preformed pipe insulation. Overlap adjoining pipe insulation by not less than two times the thickness of pipe insulation, or one pipe diameter, whichever is thicker.

7. Cover segmented insulated surfaces with a layer of finishing cement and coat with a mastic. Install vapor-barrier mastic for below ambient services and a breather mastic for above ambient services. Reinforce the mastic with fabric-reinforcing mesh. Trowel the mastic to a smooth and well-shaped contour.

8. For services not specified to receive a field-applied jacket except for flexible elastomeric and polyolefin, install fitted PVC cover over elbows, tees, strainers, valves, flanges, and unions. Terminate ends with PVC end caps. Tape PVC covers to adjoining insulation facing using PVC tape.
9. Stencil or label the outside insulation jacket of each union with the word "UNION." Match size and color of pipe labels.

C. Insulate instrument connections for thermometers, pressure gages, pressure temperature taps, test connections, flow meters, sensors, switches, and transmitters on insulated pipes, vessels, and equipment. Shape insulation at these connections by tapering it to and around the connection with insulating cement and finish with finishing cement, mastic, and flashing sealant.

D. Install removable insulation covers at locations indicated. Installation shall conform to the following:

1. Make removable flange and union insulation from sectional pipe insulation of same thickness as that on adjoining pipe. Install same insulation jacket as adjoining pipe insulation.

2. When flange and union covers are made from sectional pipe insulation, extend insulation from flanges or union long at least two times the insulation thickness over adjacent pipe insulation on each side of flange or union. Secure flange cover in place with stainless-steel or aluminum bands. Select band material compatible with insulation and jacket.

3. Construct removable valve insulation covers in same manner as for flanges except divide the two-part section on the vertical center line of valve body.

4. When covers are made from block insulation, make two halves, each consisting of mitered blocks wired to stainless-steel fabric. Secure this wire frame, with its attached insulation, to flanges with tie wire. Extend insulation at least 2 inches over adjacent pipe insulation on each side of valve. Fill space between flange or union cover and pipe insulation with insulating cement. Finish cover assembly with insulating cement applied in two coats. After first coat is dry, apply and trowel second coat to a smooth finish.

5. Unless a PVC jacket is indicated in field-applied jacket schedules, finish exposed surfaces with a metal jacket.

3.06 CELLULAR-GLASS INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of insulation to pipe with wire or bands and tighten bands without deforming insulation materials.

2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.

3. For insulation with factory-applied jackets on above ambient services, secure laps with outward clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets on below ambient services, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.
2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of cellular-glass block insulation of same thickness as pipe insulation.

4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available. Secure according to manufacturer's written instructions.

2. When preformed sections of insulation are not available, install mitered sections of cellular-glass insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of cellular-glass insulation to valve body.

2. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

3. Install insulation to flanges as specified for flange insulation application.

3.07 FLEXIBLE ELASTOMERIC INSULATION INSTALLATION

A. Seal longitudinal seams and end joints with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

B. Insulation Installation on Pipe Flanges:

1. Install pipe insulation to outer diameter of pipe flange.

2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with cut sections of sheet insulation of same thickness as pipe insulation.

4. Secure insulation to flanges and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install mitered sections of pipe insulation.

2. Secure insulation materials and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

D. Insulation Installation on Valves and Pipe Specialties:
1. Install preformed valve covers manufactured of same material as pipe insulation when available.

2. When preformed valve covers are not available, install cut sections of pipe and sheet insulation to valve body. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

3. Install insulation to flanges as specified for flange insulation application.

4. Secure insulation to valves and specialties and seal seams with manufacturer's recommended adhesive to eliminate openings in insulation that allow passage of air to surface being insulated.

3.08 MINERAL-FIBER INSULATION INSTALLATION

A. Insulation Installation on Straight Pipes and Tubes:

1. Secure each layer of preformed pipe insulation to pipe with wire or bands and tighten bands without deforming insulation materials.

2. Where vapor barriers are indicated, seal longitudinal seams, end joints, and protrusions with vapor-barrier mastic and joint sealant.

3. For insulation with factory-applied jackets on above ambient surfaces, secure laps with outward clinched staples at 6 inches o.c.

4. For insulation with factory-applied jackets on below ambient surfaces, do not staple longitudinal tabs but secure tabs with additional adhesive as recommended by insulation material manufacturer and seal with vapor-barrier mastic and flashing sealant.

B. Insulation Installation on Pipe Flanges:

1. Install preformed pipe insulation to outer diameter of pipe flange.

2. Make width of insulation section same as overall width of flange and bolts, plus twice the thickness of pipe insulation.

3. Fill voids between inner circumference of flange insulation and outer circumference of adjacent straight pipe segments with mineral-fiber blanket insulation.

4. Install jacket material with manufacturer's recommended adhesive, overlap seams at least 1 inch, and seal joints with flashing sealant.

C. Insulation Installation on Pipe Fittings and Elbows:

1. Install preformed sections of same material as straight segments of pipe insulation when available.

2. When preformed insulation elbows and fittings are not available, install mitered sections of pipe insulation, to a thickness equal to adjoining pipe insulation. Secure insulation materials with wire or bands.

D. Insulation Installation on Valves and Pipe Specialties:

1. Install preformed sections of same material as straight segments of pipe insulation when available.
2. When preformed sections are not available, install mitered sections of pipe insulation to valve body.

3. Arrange insulation to permit access to packing and to allow valve operation without disturbing insulation.

4. Install insulation to flanges as specified for flange insulation application.

E. Blanket Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer’s recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
   
a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
   
b. On duct sides with dimensions larger than 18 inches, place pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
   
c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   
d. Do not overcompress insulation during installation.
   
e. Impale insulation over pins and attach speed washers.
   
f. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
   
a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
   
b. Install vapor stops for ductwork and plenums operating below 50 degrees F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to 2 times the insulation thickness but not less than 3 inches.
5. Overlap unfaced blankets a minimum of 2 inches on longitudinal seams and end joints. At end joints, secure with steel bands spaced a maximum of 18 inches o.c.

6. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

7. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch-wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

F. Board Insulation Installation on Ducts and Plenums: Secure with adhesive and insulation pins.

1. Apply adhesives according to manufacturer’s recommended coverage rates per unit area, for 100 percent coverage of duct and plenum surfaces.

2. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.

3. Install either capacitor-discharge-weld pins and speed washers or cupped-head, capacitor-discharge-weld pins on sides and bottom of horizontal ducts and sides of vertical ducts as follows:
   a. On duct sides with dimensions 18 inches and smaller, place pins along longitudinal centerline of duct. Space 3 inches maximum from insulation end joints, and 16 inches o.c.
   b. On duct sides with dimensions larger than 18 inches, space pins 16 inches o.c. each way, and 3 inches maximum from insulation joints. Install additional pins to hold insulation tightly against surface at cross bracing.
   c. Pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   d. Do not overcompress insulation during installation.
   e. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.

4. For ducts and plenums with surface temperatures below ambient, install a continuous unbroken vapor barrier. Create a facing lap for longitudinal seams and end joints with insulation by removing 2 inches from one edge and one end of insulation segment. Secure laps to adjacent insulation section with 1/2-inch outward-clinching staples, 1 inch o.c. Install vapor barrier consisting of factory- or field-applied jacket, adhesive, vapor-barrier mastic, and sealant at joints, seams, and protrusions.
   a. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-barrier seal.
   b. Install vapor stops for ductwork and plenums operating below 50 degrees F at 18-foot intervals. Vapor stops shall consist of vapor-barrier mastic applied in a Z-shaped pattern over insulation face, along butt end.
of insulation, and over the surface. Cover insulation face and surface to be insulated a width equal to two times the insulation thickness but not less than 3 inches.

5. Install insulation on rectangular duct elbows and transitions with a full insulation section for each surface. Groove and score insulation to fit as closely as possible to outside and inside radius of elbows. Install insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.

6. Insulate duct stiffeners, hangers, and flanges that protrude beyond insulation surface with 6-inch- wide strips of same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with pins spaced 6 inches o.c.

3.09 FIELD-APPLIED JACKET INSTALLATION

A. Where FSK jackets are indicated, install as follows:

1. Draw jacket material smooth and tight.
2. Install lap or joint strips with same material as jacket.
3. Secure jacket to insulation with manufacturer’s recommended adhesive.
4. Install jacket with 1-1/2-inch laps at longitudinal seams and 3-inch- wide joint strips at end joints.
5. Seal openings, punctures, and breaks in vapor-retarder jackets and exposed insulation with vapor-barrier mastic.

B. Where metal jackets are indicated, install with 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.

3.10 FIRE-RATED INSULATION SYSTEM INSTALLATION

A. Where fire-rated insulation system is indicated, secure system to ducts and duct hangers and supports to maintain a continuous fire rating.

B. Insulate duct access panels and doors to achieve same fire rating as duct.

C. Install firestopping at penetrations through fire-rated assemblies. Fire-stop systems are specified in Section 07 84 00, Firestopping.

3.11 FINISHES

A. Duct, Equipment, and Pipe Insulation with ASJ or Other Paintable Jacket Material: Paint jacket with paint system identified below.

B. Retain paint system in subparagraphs below for a flat, latex-emulsion size over insulation covering an exterior that is subject to normal use and moderate environments.

1. Flat Acrylic Finish: Two finish coats over a primer that is compatible with jacket material and finish coat paint. Add fungicidal agent to render fabric mildew proof.
C. Flexible Elastomeric Thermal Insulation: After adhesive has fully cured, apply two coats of insulation manufacturer's recommended protective coating.

D. Color: Final color as selected by Architect. Vary first and second coats to allow visual inspection of the completed Work.

E. Do not field paint aluminum or stainless-steel jackets.

3.12 FIELD QUALITY CONTROL

A. Perform tests and inspections.

B. Tests and Inspections:

1. Inspect ductwork, 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 location(s) for each duct system defined in the "Duct Insulation Schedule, General" Article.

2. Inspect field-insulated equipment, 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 one location(s) for each type of equipment defined in Article 3.13, Duct Insulation Schedule, General herein. For large equipment, remove only a portion adequate to determine compliance.

3. 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 threaded fittings, three locations of welded fittings, two locations of threaded strainers, two locations of welded strainers, three locations of threaded valves, and three locations of flanged valves for each pipe service defined in Article 3.16, Pipe Insulation Schedule, General, herein.

C. All insulation applications will be considered defective Work if sample inspection reveals noncompliance with requirements.

3.13 DUCT INSULATION SCHEDULE, GENERAL

A. Plenums and Ducts Requiring Insulation:

1. Indoor, concealed supply and outdoor air.

2. Indoor, exposed supply and outdoor air.

3. Indoor, concealed return located in nonconditioned space.

4. Indoor, exposed return located in nonconditioned space.

5. Indoor, concealed exhaust between isolation damper and penetration of building exterior.

6. Indoor, exposed exhaust between isolation damper and penetration of building exterior.

7. Outdoor, concealed supply and return.

8. Outdoor, exposed supply and return.
B. Items Not Insulated:

1. Fibrous-glass ducts.
2. Metal ducts with duct liner of sufficient thickness to comply with energy code and ASHRAE/IESNA 90.1.
3. Factory-insulated flexible ducts.
5. Flexible connectors.
7. Factory-insulated access panels and doors.

C. Concealed, Supply-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

D. Concealed, Return-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

E. Concealed, Outdoor-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

F. Concealed, Exhaust-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

G. Exposed, Supply-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

H. Exposed, Return-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

I. Exposed, Outdoor-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

J. Exposed, Exhaust-Air Duct and Plenum Insulation: Mineral-fiber board, 2 inches thick and 1.5-lb/cu. ft. nominal density.

3.14 EQUIPMENT INSULATION SCHEDULE

A. Insulation materials and thicknesses are identified below. If more than one material is listed for a type of equipment, selection from materials listed is Contractor's option.

B. Insulate indoor and outdoor equipment in Articles below that is not factory insulated.

3.15 PIPING INSULATION SCHEDULE, GENERAL

A. Acceptable preformed pipe and tubular insulation materials and thicknesses are identified for each piping system and pipe size range. If more than one material is listed for a piping system, selection from materials listed is Contractor's option.

B. Items Not Insulated: Unless otherwise indicated, do not install insulation on the following:

1. Drainage piping located in crawl spaces.
2. Underground piping.
3. Chrome-plated pipes and fittings unless there is a potential for personnel injury.

3.16 INDOOR PIPING INSULATION SCHEDULE
A. Refrigerant Suction and Hot-Gas Piping: Flexible elastomeric, 1 inch thick.
B. Refrigerant Suction and Hot-Gas Flexible Tubing: Flexible elastomeric, 1 inch thick.

3.17 INDOOR, FIELD-APPLIED JACKET SCHEDULE
A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
B. If more than one material is listed, selection from materials listed is Contractor's option.
C. Ducts and Plenums, Concealed:
   1. None.
D. Ducts and Plenums, Exposed:
   1. Aluminum, Smooth 0.032 inch thick.
E. Equipment, Concealed:
   1. None.
F. Equipment, Exposed, up to 48 Inches in Diameter or with Flat Surfaces up to 72 Inches:
   1. Aluminum, Corrugated: 0.032 inch thick.
A. Equipment, Exposed, Larger Than 48 Inches in Diameter or with Flat Surfaces Larger Than 72 Inches:
   2. Painted Aluminum, Stucco Embossed with 1-1/4-Inch-Deep Corrugations: 0.032 inch thick.
G. Piping, Concealed:
   1. None.
H. Piping, Exposed:
   1. Aluminum, Smooth: 0.024 inch thick.

3.18 OUTDOOR, FIELD-APPLIED JACKET SCHEDULE
A. Install jacket over insulation material. For insulation with factory-applied jacket, install the field-applied jacket over the factory-applied jacket.
B. If more than one material is listed, selection from materials listed is Contractor's option.
C. Ducts and Plenums, Concealed:
D. Piping, Concealed:
   1. Aluminum, Smooth: 0.032 inch thick.
E. Piping, Exposed:
1. Aluminum, Smooth: 0.032 inch thick.

3.19 UNDERGROUND, FIELD-INSTALLED INSULATION JACKET

A. For underground direct-buried piping applications, install underground direct-buried jacket over insulation material.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 23 09 00
INSTRUMENTATION AND CONTROL FOR HVAC

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes control equipment for HVAC systems and components, including control components for terminal heating and cooling units not supplied with factory-wired controls.

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 23 05 00, Common Work Results for HVAC
2. Section 23 09 93, Sequence of Operations for HVAC Controls,
3. Section 25 60 00, Building Management System

1.02 REFERENCES

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

1. National Fire Protection Association (NFPA)
   a. 70 National Electric Code
2. Instrumentation, Systems, and Automation Society (ISA)
   a. ISA 50.00.01 Compatibility of Analog Signals for Electronic Industrial Process Instruments
3. National Electrical Manufacturers Association (NEMA)
   a. NEMA 250 Enclosures for Electrical Equipment (1000 V Maximum)
4. Air Movement and Control Association (AMCA)
   a. AMCA 500D Test Methods for Louvers, Dampers and Shutters

1.03 PROJECT COORDINATION

A. See Section 01 31 13, Project Coordination and Section 23 05 00, Common Work Results for HVAC, for requirements.

B. Coordinate equipment with Section 28 31 00, Fire Detection and Alarm, to achieve compatibility with equipment that interfaces with that system.

C. Coordinate supply of conditioned electrical branch circuits for control units and operator workstation.
D. Coordinate equipment with Section 26 29 13, Enclosed Controllers, to achieve compatibility with motor starters and annunciation devices.

1.04 SUBMITTALS

A. Product Data: For each control device indicated.

B. Shop Drawings:
   1. Schematic flow diagrams.
   2. Power, signal, and control wiring diagrams.
   3. Details of control panel faces.
   4. Damper schedule.

C. Software and firmware operational documentation.

D. Field quality-control test reports.

E. Operation and maintenance data.

1.05 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable to city of Seattle code authority, and marked for intended use.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.02 EQUIPMENT

A. Power Supplies: Transformers with Class 2 current-limiting type or overcurrent protection; limit connected loads to 80 percent of rated capacity. DC power supply shall match output current and voltage requirements and be full-wave rectifier type with the following:

   1. Output ripple of 5.0 mV maximum peak to peak.

   2. Combined 1 percent line and load regulation with 100-mic.sec. response time for 50 percent load changes.

   3. Built-in overvoltage and overcurrent protection and be able to withstand 150 percent overload for at least 3 seconds without failure.

B. Power Line Filtering: Internal or external transient voltage and surge suppression for workstations or controllers with the following:
1. Minimum dielectric strength of 1000 V.
3. Minimum transverse-mode noise attenuation of 65 dB.
4. Minimum common-mode noise attenuation of 150 dB at 40 to 100 Hz.

2.03 ELECTRONIC SENSORS

A. Description: Vibration and corrosion resistant; for wall, immersion, or duct mounting as required.

B. Thermistor Temperature Sensors and Transmitters:

1. Available Manufacturers:
   a. BEC Controls Corporation.
   b. Ebtron, Inc.
   c. Heat-Timer Corporation.
   d. I.T.M. Instruments Inc.
   e. MAMAC Systems, Inc.
   f. RDF Corporation.

2. Accuracy: Plus or minus 0.36 degreesF at calibration point.


4. Insertion Elements in Ducts: Single point, 18 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft.

5. Averaging Elements in Ducts: 72 inches long, flexible; use where prone to temperature stratification or where ducts are larger than 10 sq. ft.

6. Insertion Elements for Liquids: Brass or stainless-steel socket with minimum insertion length of 2-1/2 inches.

7. Room Sensor Cover Construction: Manufacturer’s standard locking covers.
   a. Set-Point Adjustment: Exposed.
   b. Set-Point Indication: Keyed.
   c. Thermometer: Exposed.
   d. Color:
   e. Orientation: Vertical.

8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.

9. Transmitter output signal: 4-20mAmp, loop powered.

C. RTDs and Transmitters:
1. Available Manufacturers:
   a. BEC Controls Corporation.
   b. MAMAC Systems, Inc.
   c. RDF Corporation.

2. Accuracy: Plus or minus 0.2 percent at calibration point.


4. Insertion Elements in Ducts: Single point, 18 inches long; use where not affected by temperature stratification or where ducts are smaller than 9 sq. ft.

5. Averaging Elements in Ducts: 48 inches long, rigid; use where prone to temperature stratification or where ducts are larger than 9 sq. ft.; length as required.

6. Insertion Elements for Liquids: Brass socket with minimum insertion length of 2-1/2 inches.

7. Room Sensor Cover Construction: Manufacturer's standard locking covers.
   a. Set-Point Adjustment: Exposed.
   b. Set-Point Indication: Keyed Exposed.
   d. Orientation: Vertical.

8. Outside-Air Sensors: Watertight inlet fitting, shielded from direct sunlight.

9. Transmitter output signal: 4-20mA, loop powered.

D. Pressure Transmitters/Transducers:

1. Available Manufacturers:
   a. BEC Controls Corporation.
   b. General Eastern Instruments.
   c. MAMAC Systems, Inc.
   d. ROTRONIC Instrument Corp.
   e. TCS/Basys Controls.
   f. Vaisala.

2. Air Differential-Pressure Transducers: apropriat diaphragm construction, suitable for service; minimum -4 to 10 inches of water operating pressure and tested to 12 inches of water; linear output 4 to 20 mA.

3. Differential-Pressure Switch (Air or Water): Snap acting, with pilot-duty rating and with suitable scale range and differential.
4. Pressure Transmitters: Direct acting for gas or liquid service; range suitable for system; linear output 4 to 20 mA.

E. Room Sensor Cover Construction: Manufacturer's standard locking covers.
2. Orientation: Vertical.

F. Room sensor accessories include the following:
1. Insulating Bases: For sensors located on exterior walls.
2. Guards Locking, solid metal, ventilated.
3. Adjusting Key: As required for calibration and cover screws.

2.04 STATUS SENSORS

A. Status Inputs for Fans: Differential-pressure switch with pilot-duty rating and with adjustable range of 0- to 5-inch wg. Wire to control terminals as “Run Feedback” signal.

B. Status Inputs for Pumps: Differential-pressure switch with pilot-duty rating and with adjustable pressure-differential range of 8 to 60 psig, piped across pump. Wire to control terminals as “Run Feedback” signal.

C. Electronic Valve/Damper Position Indicator: Visual scale indicating percent of travel and 2- to 10-V dc, feedback signal.

D. Water-Flow Switches: Bellows-actuated mercury or snap-acting type with pilot-duty rating, stainless-steel or bronze paddle, with appropriate range and differential adjustment, in NEMA 250, Type 1 enclosure.
1. Available Manufacturers:
   a. BEC Controls Corporation.
   b. I.T.M. Instruments Inc.

2.05 ACTUATORS

A. Electronic Actuators: Direct-coupled type designed for minimum 60,000 full-stroke cycles at rated torque.
1. Available Manufacturers:
   a. Belimo Aircontrols (USA), Inc.
   b. Valves: Size for torque required for valve close off at maximum pump differential pressure.

2. Dampers: Size for running torque calculated as follows:
   b. Opposed-Blade Damper with Edge Seals: 5 inch-lb/sq. ft. of damper.
d. Opposed-Blade Damper without Edge Seals: 3 inch-lb/sq. ft. of damper.

e. Dampers with 2- to 3-Inch wg of Pressure Drop or Face Velocities of 1000 to 2500 fpm: Increase running torque by 1.5.

f. Dampers with 3- to 4-Inch wg of Pressure Drop or Face Velocities of 2500 to 3000 fpm: Increase running torque by 2.0.


4. Overload Protection: Electronic overload or digital rotation-sensing circuitry.

5. Fail-Safe Operation: Mechanical, spring-return mechanism. Provide external, manual gear release on nonspring-return actuators.


8. Proportional Signal: 4 to 20 mA, and 2- to 10-V dc position feedback signal.

9. Temperature Rating: Minus 22 to plus 122 degreesF.

10. Temperature Rating (Smoke Dampers): Minus 22 to plus 250 degreesF.

11. Run Time: 60 seconds.

2.06 DAMPERS SEE SECTION 23 33 00, AIR DUCT ACCESSORIES

2.07 CONTROL CABLE

A. Electronic and fiber-optic cables for control wiring are specified in Division 27 Section "Communications Horizontal Cabling."

PART 3 - EXECUTION

3.01 INSTALLATION

A. Verify location of thermostats, and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above the floor.

1. Install averaging elements in ducts and plenums in crossing or zigzag pattern.

B. Install guards on thermostats in the following locations:

1. Entrances.

2. Public areas.

3. Where indicated.

C. Install automatic dampers according to Section 23 33 00, Air Duct Accessories.

D. Install damper motors on outside of duct in warm areas, not in locations exposed to outdoor temperatures.

E. Install labels and nameplates to identify control components according to Section 23 05 53, Identification for HVAC Piping and Equipment.
F. Install refrigerant instrument wells, valves, and other accessories according to Section 23 23 00, Section Refrigerant Piping.

G. Install duct volume-control dampers according to Division 23, Heating, Ventilation, and Air Conditioning (HVA), Sections specifying air ducts.

H. Install electronic and fiber-optic cables according to Division 26 Sections.

3.02 ELECTRICAL WIRING AND CONNECTION INSTALLATION

A. Install raceways, boxes, and cabinets according to Section 26 05 33, Raceway and Boxes for Electrical Systems.

B. Install building wire and cable according to Division 26 Sections.

C. Install signal and communication cable according to Division 26 Sections.

1. Conceal cable, except in mechanical rooms and areas where other conduit and piping are exposed.

2. Install exposed cable in raceway.

3. Install concealed cable in raceway.

4. Bundle and harness multiconductor instrument cable in place of single cables where several cables follow a common path.

5. Fasten flexible conductors, bridging cabinets and doors, along hinge side; protect against abrasion. Tie and support conductors.

6. Number-code or color-code conductors for future identification and service of control system, except local individual room control cables.

7. Install wire and cable with sufficient slack and flexible connections to allow for vibration of piping and equipment.

D. Connect manual-reset limit controls independent of manual-control switch positions. Automatic duct heater resets may be connected in interlock circuit of power controllers.

E. Connect hand-off-auto selector switches to override automatic interlock controls when switch is in hand position.

F. Provide control terminals arranged as shown on building management plans.

3.03 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

1. Operational Test: After electrical circuitry has been energized, start units to confirm proper unit operation. Remove and replace malfunctioning units and retest.

2. Test and adjust controls and safeties.

3. Test calibration of controllers by disconnecting input sensors and stimulating operation with compatible signal generator.
4. Test each point through its full operating range to verify that safety and operating control set points are as required.

5. Test each control loop to verify stable mode of operation and compliance with sequence of operation. Adjust PID actions.

6. Test each system for compliance with sequence of operation.

7. Test software and hardware interlocks.

B. DDC Verification:

1. Verify that instruments are installed before calibration, testing, and loop or leak checks.

2. Check instruments for proper location and accessibility.

3. Check instrument installation for direction of flow, elevation, orientation, insertion depth, and other applicable considerations.

4. Check instrument tubing for proper fittings, slope, material, and support.

5. Check pressure instruments, piping slope, installation of valve manifold, and self-contained pressure regulators.

6. Check temperature instruments and material and length of sensing elements.

7. Check air-operated dampers. Verify that pressure gages are provided and that proper blade alignment, either parallel or opposed, has been provided.

C. Replace damaged or malfunctioning controls and equipment and repeat testing procedures.

3.04 DEMONSTRATION

A. Engage a factory-authorized service representative to train Sound Transit’s maintenance personnel to adjust, operate, and maintain HVAC instrumentation and controls. Refer to Section 01 75 50, System Start-Up and Testing.

END OF SECTION
SECTION 23 09 93
SEQUENCE OF OPERATIONS FOR HVAC CONTROLS

1.01 SUMMARY
A. This Section includes control sequences for HVAC systems, subsystems, and equipment.
B. Related Documents include Building Management drawings.
C. Related Sections include the following:
   1. Section 23 09 00, Instrumentation and Control for HVAC, for control equipment and devices and for submittal requirements.
   2. Section 25 60 00, Building Management System.

1.02 DEFINITIONS
A. DDC: Direct digital control.

1.03 SCHEDULED OPERATION:
A. Occupied and unoccupied periods on seven 365-day clock with a minimum of four programmable periods per day.
   1. Unoccupied Period:
      a. Heating Setback: 10 degrees F.
      b. Cooling Setback: over ride on.
      c. Override Operation: Two hours.

1.04 AIR-HANDLING-UNIT CONTROL SEQUENCES FOR THE FOLLOWING SYSTEMS AHU-2, AHU-19, AHU-06, AHU-09, AHU-10, AHU-07, AHU-11, AHU-03, SEE THE UNIT CONTROL ASSCIATION TABLE.
A. Start and Stop Supply Fan(s):
   1. Start fan during occupied setting adjustable.
      a. Occupied Periods: Run fan continuously.
      b. Unoccupied Periods: Cycle fan to maintain setback temperature.
      c. Duct smoke detector will shut down supply fan.
B. Associated Exhaust Fan: start fan with AHU.
C. Associated Fire Smoke Dampers: open when AHU operates
D. Associated Electric-Heating-Coil Operation:
   1. Occupied Periods: Stage coil to maintain duct supply temperature of 44 degrees F.
2. Unoccupied Periods: Energize coil to maintain setback temperature.

E. Associated Mixing Damper, Economizer Outdoor-Air Damper Operation:

1. Occupied Periods: Open to 50 percent fixed minimum intake, and maximum 100 percent of the fan capacity to comply with ASHRAE Cycle II. Controller shall permit air-side economizer operation when room temperature set points are greater than 72 degrees F. Use mixed-air and outdoor-air temperature to adjust mixing dampers. During economizer cycle operation.

2. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

F. Fire / Smoke Control:

1. All fans and associated devices will shut down when the fire alarm panel detects smoke in the station.

1.05 AIR-HANDLING-UNIT CONTROL SEQUENCES FOR THE FOLLOWING SYSTEMS AHU-01, AHU-13

A. Start and Stop Supply Fan(s):

1. Start fan during occupied setting adjustable.
   a. Occupied Periods: Run fan continuously.
   b. Unoccupied Periods: Cycle fan to maintain setback temperature.
   c. Duct smoke detector will shut down supply fan.

B. Associated Exhaust Fan: start fan with AHU.

C. Associated Fire Smoke Dampers: open when AHU operates

D. Associated Electric-Heating-Coil Operation:

1. Occupied Periods: Stage coil to maintain duct supply temperature of 44 degrees F.

2. Unoccupied Periods: Energize coil to maintain setback temperature.

E. Associated Mixing Damper, Economizer Outdoor-Air Damper Operation:

1. Occupied Periods: Open to 50 percent fixed minimum intake, and maximum 100 percent of the fan capacity to comply with ASHRAE Cycle II. Controller shall permit air-side economizer operation when room temperature set points are greater than 72 degrees F. Use mixed-air and outdoor-air temperature to adjust mixing dampers. During economizer cycle operation.

2. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

F. Fire / Smoke Control:

1. All fans and associated devices will shut down when the fire alarm panel detects smoke in the station.

G. Clean Agent Discharge:
1. All fans and associated devices will shut down when the clean agent system discharges.

### 1.06 AIR-HANDLING-UNIT CONTROL SEQUENCES FOR THE FOLLOWING SYSTEMS AHU-04/AHU-15, AND AHU-16/AHU-17

A. Both sets operate as a system:

1. AHU that has heat is the primary unit which runs continuously.
2. AHU without heat operates when room temperature reaches 78 degrees F adjustable.

B. Start and Stop Supply Fan(s):

1. Start fan during occupied setting adjustable.
   a. Occupied Periods: Run fan continuously.
   b. Unoccupied Periods: Cycle fan to maintain setback temperature.
   c. Duct smoke detector will shut down supply fan.

C. Associated Exhaust Fan: start fan with AHU.

D. Associated Fire Smoke Dampers: open when AHU operates

E. Associated Electric-Heating-Coil Operation:

1. Occupied Periods: Stage coil to maintain duct supply temperature of 44 degrees F.
2. Unoccupied Periods: Energize coil to maintain setback temperature.

F. Associated Mixing Damper, Economizer Outdoor-Air Damper Operation:

1. Occupied Periods: Open to 50 percent fixed minimum intake, and maximum 100 percent of the fan capacity to comply with ASHRAE Cycle II. Controller shall permit air-side economizer operation when room temperature set points are greater than 72 degrees F. Use mixed-air and outdoor-air temperature to adjust mixing dampers. During economizer cycle operation.
2. Unoccupied Periods: Close outdoor-air damper and open return-air damper.

G. Fire / Smoke Control:

1. All fans and associated devices will shut down when the fire alarm panel detects smoke in the station.

### 1.07 AIR-CONDITIONING UNIT CONTROL SEQUENCES FOR THE FOLLOWING SYSTEMS ACU-01, ACU-03, ACU-04, ACU-05, ACU-06, ACU-07, ACU-02

A. Units all operate as room temperature require set points are 68 degrees F heating and 74 degrees F adjustable.

B. Start and Stop Supply Fan(s):

1. Start fan when required.
a. Duct smoke detector will shut down supply fan.

C. Associated compressor unit operate as required.

D. Associated Electric-Heating-Coil Operation as required:

E. Fire / Smoke Control:

1. All fans and associated devices will shut down when the fire alarm panel detects smoke in the station.

F. Clean Agent Discharge:

1. All fans and associated devices will shut down when the clean agent system discharges.

1.08 AIR-HANDLING-UNIT CONTROL SEQUENCES FOR THE FOLLOWING SYSTEMS AHU-03 AHU-08, AHU-12, AHU-15, AHU-14 SEE THE UNIT CONTROL ASSCIATION TABLE.

A. Start and Stop Supply Fan(s):

1. Start fan during station smoke signal from fire control panel.

B. Associated motor damper: damper shall modulate open to maintain stair/elevator pressurization of 2.5 inches of water.

C. Associated Fire Smoke Dampers: open when AHU operates

1.09 FIRE SMOKE DAMPERS FOR ELEVATORS NOT PRESSURIZED, FSD-99, FSD-100, FSD-101

A. Dampers normally closed.

B. Open damper when smoke is detected in elevator shaft.

1.10 ALL PUMPS

A. Pumps shall operate when float controls indicate.

B. Pumps with redundancy shall operate with alternating primary, standby control.

1.11 OPERATOR STATION DISPLAY MONITORING INDICATES THE FOLLOWING ON OPERATOR WORKSTATION DISPLAY TERMINAL:

A. DDC system graphic.

B. DDC system on-off indication.

C. DDC system occupied/unoccupied mode.

D. Outdoor-air-temperature indication.

E. Supply-fan on-off indication.

F. Supply-fan-discharge static-pressure indication.

G. Supply-fan-discharge static-pressure set point.

H. Building static-pressure indication.
I. Building static-pressure set point.
J. Mixed-air-temperature indication.
K. Mixed-air-temperature set point.
L. Mixed-air damper position.
M. Filter air-pressure-drop indication.
N. Filter low-air-pressure set point.
O. Filter high-air-pressure set point.
P. Fan-discharge air-temperature indication.
Q. Fan-discharge air-temperature set point.
R. Heating-coil air-temperature indication.
S. Heating-coil air-temperature set point.
T. Cooling-coil air-temperature indication.
U. Cooling-coil air-temperature set point.
V. Room temperature indication.
W. Room temperature set point.
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PART 2 - PRODUCTS (NOT USED)

PART 3 - EXECUTION (NOT USED)

END OF SECTION
SECTION 23 23 00
REFRIGERANT PIPING

PART 1 - GENERAL

1.01 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01, General Requirements Specification Sections, apply to this Section.

1.02 SUMMARY

A. This Section includes refrigerant piping used for air-conditioning applications.

1.03 REFERENCES

1. American Society of Mechanical Engineers (ASME)
   a. Boiler and Pressure Vessel Code (BPVC), Section IX, Welding and Brazing Qualifications
   b. B31.5 Refrigeration Piping and Heat Transfer Components
   c. B16.22 Wrought Copper and Copper Alloy Solder Joint Pressure Fittings
   d. B16.5 Pipe Flanges and Flanged Fittings
   e. B1.20.2 Pipe Threads, General Purpose (inch)
   f. B31.5 Power Piping and Process Piping SET

   a. ASTM B280 Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
   b. ASTM B 32 Solder Metal
   c. ASTM A 53/53M Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
   d. ASTM A 234/234M Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service
   e. ASTM B828 Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

3. Manufacturers Standardization Society for the Valve and Fittings Industry
   a. MSS SP-58 Pipe Hangers and Supports – Materials, Design and Manufacture

4. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
a. ASHRAE 15 Safety Standards for Refrigeration Systems
b. ASHRAE 34 Designation and Safety Classification of Refrigerants

5. American Welding Society (AWS)
   AWS 5.8 Filler Metals for Brazing and Braze Welding

6. The Air-Conditioning and Refrigeration Institute (ARI)
   a. ARI 760 Solenoid Valves for Use with Volatile Refrigerators
   b. ARI 750 Thermostatic Refrigeration Expansion Valves
   c. ARI 730 Flow-Capacity Rating and Application of Suction-Line Filters and Driers
   d. ARI 495 Refrigerant Liquid Receivers

1.04 PERFORMANCE REQUIREMENTS

A. Line Test Pressure for Refrigerant R-22:
   3. Hot-Gas and Liquid Lines: 325 psig.

B. Line Test Pressure for Refrigerant R-134a:

C. Line Test Pressure for Refrigerant R-407C:

D. Line Test Pressure for Refrigerant R-410A:
1.05 SUBMITTALS

A. Product Data: For each type of valve and refrigerant piping specialty indicated. Include pressure drop, based on manufacturer's test data, for the following:

1. Thermostatic expansion valves.
2. Solenoid valves.
3. Hot-gas bypass valves.
4. Filter dryers.
5. Strainers.
6. Pressure-regulating valves.

B. Shop Drawings: Show layout of refrigerant piping and specialties, including pipe, tube, and fitting sizes, flow capacities, valve arrangements and locations, slopes of horizontal runs, oil traps, double risers, wall and floor penetrations, and equipment connection details. Show interface and spatial relationships between piping and equipment.

1. Shop Drawing Scale: 1/4 inch equals 1 foot.
2. Refrigerant piping indicated on Drawings is schematic only. Size piping and design actual piping layout, including oil traps, double risers, specialties, and pipe and tube sizes to accommodate, as a minimum, equipment provided, elevation difference between compressor and evaporator, and length of piping to ensure proper operation and compliance with warranties of connected equipment.

C. Welding certificates.
D. Field quality-control test reports.
E. Operation and Maintenance Data: For refrigerant valves and piping specialties to include in maintenance manuals.

1.06 QUALITY ASSURANCE

A. Welding: Qualify procedures and personnel according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."


C. Comply with ASME B31.5, "Refrigeration Piping and Heat Transfer Components."

1.07 PRODUCT STORAGE AND HANDLING

A. Store piping in a clean and protected area with end caps in place to ensure that piping interior and exterior are clean when installed.

1.08 COORDINATION

A. Coordinate size and location of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 07 72 00, Roof Accessories.
PART 2 - PRODUCTS

2.01 COPPER TUBE AND FITTINGS

A. Copper Tube: ASTM B 280, Type ACR.
B. Wrought-Copper Fittings: ASME B16.22.
C. Wrought-Copper Unions: ASME B16.22.
D. Solder Filler Metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.
E. Brazing Filler Metals: AWS A5.8.
F. Flexible Connectors:
   2. End Connections: Socket ends.
   3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.
   5. Maximum Operating Temperature: 250 degrees F.

2.02 STEEL PIPE AND FITTINGS

A. Steel Pipe: ASTM A 53/A 53M, black steel with plain ends; Type, Grade, and wall thickness as selected in Part 3 piping applications articles.
B. Wrought-Steel Fittings: ASTM A 234/A 234M, for welded joints.
C. Steel Flanges and Flanged Fittings: ASME B16.5, steel, including bolts, nuts, and gaskets, bevel-welded end connection, and raised face.
E. Flanged Unions:
   1. Body: Forged-steel flanges for NPS 1 to NPS 1-1/2 and ductile iron for NPS 2 to NPS 3. Apply rust-resistant finish at factory.
   2. Gasket: Fiber asbestos free.
   3. Fasteners: Four plated-steel bolts, with silicon bronze nuts. Apply rust-resistant finish at factory.
   4. End Connections: Brass tailpiece adapters for solder-end connections to copper tubing.
   5. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch-long assembly.

7. Maximum Operating Temperature: 330 degrees F.

F. Flexible Connectors:


2. End Connections:
   a. NPS 2 and Smaller: With threaded-end connections.
   b. NPS 2-1/2 and Larger: With flanged-end connections.

3. Offset Performance: Capable of minimum 3/4-inch misalignment in minimum 7-inch- long assembly.


5. Maximum Operating Temperature: 250 degrees F.

2.03 VALVES AND SPECIALTIES

A. Diaphragm Packless Valves:

1. Body and Bonnet: Forged brass or cast bronze; globe design with straight-through or angle pattern.


3. Operator: Rising stem and hand wheel.


5. End Connections: Socket, union, or flanged.


7. Maximum Operating Temperature: 275 degrees F.

B. Packed-Angle Valves:

1. Body and Bonnet: Forged brass or cast bronze.

2. Packing: Molded stem, back seating, and replaceable under pressure.

3. Operator: Rising stem.


5. Seal Cap: Forged-brass or valox hex cap.

6. End Connections: Socket, union, threaded, or flanged.


8. Maximum Operating Temperature: 275 degrees F.
C. Check Valves:
1. Body: Ductile iron, forged brass, or cast bronze; globe pattern.
2. Bonnet: Bolted ductile iron, forged brass, or cast bronze; or brass hex plug.
6. End Connections: Socket, union, threaded, or flanged.
7. Maximum Opening Pressure: 0.50 psig.
9. Maximum Operating Temperature: 275 degrees F.

D. Service Valves:
1. Body: Forged brass with brass cap including key end to remove core.
2. Core: Removable ball-type check valve with stainless-steel spring.
4. End Connections: Copper spring.

E. Solenoid Valves: Comply with ARI 760 and UL 429; listed and labeled by an NRTL.
4. End Connections: Threaded.
5. Electrical: Molded, watertight coil in NEMA 250 enclosure of type required by location with 1/2-inch conduit adapter, and 24 OR115-V ac coil.
7. Maximum Operating Temperature: 240 degrees F.

F. Safety Relief Valves: Comply with ASME Boiler and Pressure Vessel Code; listed and labeled by an NRTL.
1. Body and Bonnet: Ductile iron and steel, with neoprene O-ring seal.
4. End Connections: Threaded.
6. Maximum Operating Temperature: 240 degrees F.

G. Thermostatic Expansion Valves: Comply with ARI 750.
1. Body, Bonnet, and Seal Cap: Forged brass or steel.
4. Capillary and Bulb: Copper tubing filled with refrigerant charge.
5. Suction Temperature: 40 degrees F.
7. Reverse-flow option (for heat-pump applications).
8. End Connections: Socket, flare, or threaded union.

H. Hot-Gas Bypass Valves: Comply with UL 429; listed and labeled by an NRTL.
1. Body, Bonnet, and Seal Cap: Ductile iron or steel.
5. Seat: Polytetrafluoroethylene.
7. Electrical: Molded, watertight coil in NEMA 250 enclosure of type required by location with 1/2-inch conduit adapter, and 24 or 115-V ac coil.
9. Set Pressure: as manufacture recommends
10. Throttling Range: Maximum 5 psig.
12. Maximum Operating Temperature: 240 degrees F.

I. Straight-Type Strainers:
2. Screen: 100-mesh stainless steel.
3. End Connections: Socket or flare.
5. Maximum Operating Temperature: 275 degrees F.

J. Angle-Type Strainers:
1. Body: Forged brass or cast bronze.
2. Drain Plug: Brass hex plug.
3. Screen: 100-mesh monel.
4. End Connections: Socket or flare.
6. Maximum Operating Temperature: 275 degrees F.

K. Moisture/Liquid Indicators:
2. Window: Replaceable, clear, fused glass window with indicating element protected by filter screen.
3. Indicator: Color coded to show moisture content in ppm.
5. End Connections: Socket or flare.
7. Maximum Operating Temperature: 240 degrees F.

L. Replaceable-Core Filter Dryers: Comply with ARI 730.
1. Body and Cover: Painted-steel shell with ductile-iron cover, stainless-steel screws, and neoprene gaskets.
2. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
4. Designed for reverse flow (for heat-pump applications).
5. End Connections: Socket.
8. Rated Flow: as required by manufacture
10. Maximum Operating Temperature: 240 degrees F.

M. Permanent Filter Dryers: Comply with ARI 730.
2. Filter Media: 10 micron, pleated with integral end rings; stainless-steel support.
4. Designed for reverse flow (for heat-pump applications).
5. End Connections: Socket.
8. Rated Flow: as required by manufacture
10. Maximum Operating Temperature: 240 degrees F.

N. Mufflers:
2. End Connections: Socket or flare.
4. Maximum Operating Temperature: 275 degrees F.

O. Receivers: Comply with ARI 495.
1. Comply with ASME Boiler and Pressure Vessel Code; listed and labeled by an NRTL.
2. Comply with UL 207; listed and labeled by an NRTL.
4. Tappings: Inlet, outlet, liquid level indicator, and safety relief valve.
5. End Connections: Socket or threaded.
7. Maximum Operating Temperature: 275 degrees F.

P. Liquid Accumulators: Comply with ARI 495.
2. End Connections: Socket or threaded.
4. Maximum Operating Temperature: 275 degrees F.
2.04 REFRIGERANTS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

   1. Atofina Chemicals, Inc.
   2. DuPont Company; Fluorochemicals Div.
   3. Honeywell, Inc.; Genetron Refrigerants.
   4. INEOS Fluor Americas LLC.

C. ASHRAE 34, R-22: Monochlorodifluoromethane.

D. ASHRAE 34, R-134a: Tetrafluoroethane.

E. ASHRAE 34, R-407C: Difluoromethane/Pentafluoroethane/1,1,1,2-Tetrafluoroethane.

F. ASHRAE 34, R-410A: Pentafluoroethane/Difluoromethane.

PART 3 - EXECUTION

3.01 PIPING APPLICATIONS FOR REFRIGERANT R-22

A. Suction Lines NPS 1-1/2 and Smaller for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

B. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

C. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications:

   1. NPS 1-1/2 and Smaller: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

D. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.

E. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with soldered joints.

F. Safety-Relief-Valve Discharge Piping:

   1. NPS 1-1/2 and Smaller: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

3.02 PIPING APPLICATIONS FOR REFRIGERANT R-134A

A. Suction Lines NPS 1-1/2 and Smaller for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.
B. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

C. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications:
   1. NPS 1-1/2 and Smaller: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

D. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.

E. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with soldered joints.

F. Safety-Relief-Valve Discharge Piping:
   1. NPS 1-1/2 and Smaller: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

3.03 PIPING APPLICATIONS FOR REFRIGERANT R-407C

A. Suction Lines NPS 1-1/2 and Smaller for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

B. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.

C. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications:
   1. NPS 1 and Smaller: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.
   2. NPS 1-1/4 to NPS 2: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.

D. Safety-Relief-Valve Discharge Piping: Schedule 40, black-steel and wrought-steel fittings with welded joints.

E. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with soldered joints.

F. Safety-Relief-Valve Discharge Piping:
   1. NPS 1 and Smaller: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.
   2. NPS 1 and Smaller: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.
   3. NPS 1-1/4 to NPS 2: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.

3.04 PIPING APPLICATIONS FOR REFRIGERANT R-410A

A. Suction Lines NPS 1-1/2 and Smaller for Conventional Air-Conditioning Applications: Copper, Type ACR, annealed-temper tubing and wrought-copper fittings with brazed or soldered joints.
B. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications: Copper, Type ACR, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.

C. Hot-Gas and Liquid Lines, and Suction Lines for Heat-Pump Applications:
   1. NPS 5/8 and Smaller: Copper, Type ACR, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.
   2. NPS 3/4 to NPS 1 and Smaller: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.
   3. NPS 1-1/4 and Smaller: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.

D. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.

E. Safety-Relief-Valve Discharge Piping: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.

F. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.

G. Safety-Relief-Valve Discharge Piping: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.

H. Safety-Relief-Valve Discharge Piping:
   1. NPS 5/8 and Smaller: Copper, Type ACR, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.
   2. NPS 3/4 to NPS 1 and Smaller: Copper, Type K, annealed- or drawn-temper tubing and wrought-copper fittings with brazed or soldered joints.
   3. NPS 1-1/4 and Smaller: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with 95-5 tin-antimony soldered joints.
   4. NPS 1-1/2 to NPS 2: Copper, Type ACR, drawn-temper tubing and wrought-copper fittings with Alloy HB soldered joints.

3.05 VALVE AND SPECIALTY APPLICATIONS

A. Install diaphragm packless valves in suction and discharge lines of compressor.

B. Install service valves for gage taps at inlet and outlet of hot-gas bypass valves and strainers if they are not an integral part of valves and strainers.

C. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.

D. Except as otherwise indicated, install diaphragm packless valves on inlet and outlet side of filter dryers.

E. Install a full-sized, three-valve bypass around filter dryers.

F. Install solenoid valves upstream from each expansion valve and hot-gas bypass valve. Install solenoid valves in horizontal lines with coil at top.
G. Install thermostatic expansion valves as close as possible to distributors on evaporators.
   1. Install valve so diaphragm case is warmer than bulb.
   2. Secure bulb to clean, straight, horizontal section of suction line using two bulb straps. Do not mount bulb in a trap or at bottom of the line.
   3. If external equalizer lines are required, make connection where it will reflect suction-line pressure at bulb location.

H. Install safety relief valves where required by ASME Boiler and Pressure Vessel Code. Pipe safety-relief-valve discharge line to outside according to ASHRAE 15.

I. Install moisture/liquid indicators in liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube.

J. Install strainers upstream from and adjacent to the following unless they are furnished as an integral assembly for device being protected:
   1. Solenoid valves.
   2. Thermostatic expansion valves.
   3. Hot-gas bypass valves.
   4. Compressor.

K. Install filter dryers in liquid line between compressor and thermostatic expansion valve, and in the suction line at the compressor.

L. Install receivers sized to accommodate pump-down charge.

M. Install flexible connectors at compressors.

3.06 PIPING INSTALLATION

A. 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 on Shop Drawings.

B. Install refrigerant piping according to ASHRAE 15.

C. Install piping in concealed locations unless otherwise indicated and except in equipment rooms and service areas.

D. Install piping indicated to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically indicated otherwise.

E. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.

F. Install piping adjacent to machines to allow service and maintenance.

G. Install piping free of sags and bends.

H. Install fittings for changes in direction and branch connections.
I. Select system components with pressure rating equal to or greater than system operating pressure.

J. Refer to Section 23 09 00, Instrumentation and Control for HVAC, and Section 23 09 93, "Sequence of Operation for HVAC Controls, for solenoid valve controllers, control wiring, and sequence of operation.

K. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.

L. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in Section 08 31 00, Access Doors and Panels, if valves or equipment requiring maintenance is concealed behind finished surfaces.

M. Install refrigerant piping in protective conduit where installed belowground.

N. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.

O. Slope refrigerant piping as follows:
   1. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
   2. Install horizontal suction lines with a uniform slope downward to compressor.
   3. Install traps and double risers to entrain oil in vertical runs.
   4. Liquid lines may be installed level.

P. When brazing or soldering, remove solenoid-valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion-valve bulb.

Q. Before installation of steel refrigerant piping, clean pipe and fittings using the following procedures:
   1. Shot blast the interior of piping.
   2. Remove coarse particles of dirt and dust by drawing a clean, lintless cloth through tubing by means of a wire or electrician's tape.
   3. Draw a clean, lintless cloth saturated with trichloroethylene through the tube or pipe. Continue this procedure until cloth is not discolored by dirt.
   4. Draw a clean, lintless cloth, saturated with compressor oil, squeezed dry, through the tube or pipe to remove remaining lint. Inspect tube or pipe visually for remaining dirt and lint.
   5. Finally, draw a clean, dry, lintless cloth through the tube or pipe.
   6. Safety-relief-valve discharge piping is not required to be cleaned but is required to be open to allow unrestricted flow.

R. Install pipe sleeves at penetrations in exterior walls and floor assemblies.
S. Seal penetrations through fire and smoke barriers according to Section 07 84 00 Firestopping.

T. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.

U. Install sleeves through floors, walls, or ceilings, sized to permit installation of full-thickness insulation.

V. Seal pipe penetrations through exterior walls according to Division 07 Section 07 92 00, Joint Sealants, for materials and methods.

W. Identify refrigerant piping and valves according to Section 23 05 53, Identification for HVAC Piping and Equipment.

3.07 PIPE JOINT CONSTRUCTION

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

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

C. Fill pipe and fittings with an inert gas (nitrogen or carbon dioxide), during brazing or welding, to prevent scale formation.

D. Soldered Joints: Construct joints according to ASTM B 828 or CDA’s “Copper Tube Handbook.”

E. Brazed Joints: Construct joints according to AWS’s “Brazing Handbook,” Chapter “Pipe and Tube.”
   1. Use Type BcuP, copper-phosphorus alloy for joining copper socket fittings with copper pipe.
   2. Use Type BAg, cadmium-free silver alloy for joining copper with bronze or steel.

F. Threaded Joints: Thread steel 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:
   1. Apply appropriate tape or thread compound to external pipe threads unless dry-seal threading is specified.
   2. Damaged Threads: Do not use pipe or pipe fittings with threads that are corroded or damaged. Do not use pipe sections that have cracked or open welds.

G. Steel pipe can be threaded, but threaded joints must be seal brazed or seal welded.

H. Welded Joints: Construct joints according to AWS D10.12/D10.12M.

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

A. Hanger, support, and anchor products are specified in Section 23 05 29, Hangers and Supports for HVAC Piping and Equipment.

B. Install the following pipe attachments:
   1. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
   2. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
   3. Pipe Roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
   4. Spring hangers to support vertical runs.
   5. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.

C. Install hangers for copper tubing with the following maximum spacing and minimum rod sizes:
   1. NPS 1/2: Maximum span, 60 inches; minimum rod size, 1/4 inch.
   2. NPS 5/8: Maximum span, 60 inches; minimum rod size, 1/4 inch.
   3. NPS 1: Maximum span, 72 inches; minimum rod size, 1/4 inch.
   4. NPS 1-1/4: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   5. NPS 1-1/2: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   6. NPS 2: Maximum span, 96 inches; minimum rod size, 3/8 inch.
   7. NPS 2-1/2: Maximum span, 108 inches; minimum rod size, 3/8 inch.

D. Install hangers for steel piping with the following maximum spacing and minimum rod sizes:
   1. NPS 2: Maximum span, 10 feet; minimum rod size, 3/8 inch.
   2. NPS 2-1/2: Maximum span, 11 feet; minimum rod size, 3/8 inch.

E. Support multifloor vertical runs at least at each floor.

3.09  FIELD QUALITY CONTROL

A. Perform tests and inspections and prepare test reports.

B. Tests and Inspections:
   1. Comply with ASME B31.5, Chapter VI.
   2. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
3. Test high- and low-pressure side piping of each system separately at not less than the pressures indicated in Part 1 "Performance Requirements" Article.
   a. Fill system with nitrogen to the required test pressure.
   b. System shall maintain test pressure at the manifold gage throughout duration of test.
   c. Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
   d. Remake leaking joints using new materials, and retest until satisfactory results are achieved.

3.10 SYSTEM CHARGING
A. Charge system using the following procedures:
   1. Install core in filter dryers after leak test but before evacuation.
   2. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, system is ready for charging.
   3. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
   4. Charge system with a new filter-dryer core in charging line.

3.11 ADJUSTING
A. Adjust thermostatic expansion valve to obtain proper evaporator superheat.
B. Adjust high- and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.
C. Adjust set-point temperature of air-conditioning or chilled-water controllers to the system design temperature.
D. Perform the following adjustments before operating the refrigeration system, according to manufacturer's written instructions:
   1. Open shutoff valves in condenser water circuit.
   2. Verify that compressor oil level is correct.
   3. Open compressor suction and discharge valves.
   4. Open refrigerant valves except bypass valves that are used for other purposes.
   5. Check open compressor-motor alignment and verify lubrication for motors and bearings.
E. Replace core of replaceable filter dryer after system has been adjusted and after design flow rates and pressures are established.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 23 30 10

TUNNEL VENTILATION EQUIPMENT

PART 1 - GENERAL

1.01 SUMMARY

A. The work specified in this section includes furnishing, installing, connecting and testing the following equipment for tunnel ventilation and smoke exhaust systems.

1. Emergency fans
2. Smoke exhaust fans
3. Fan motors
4. Fan motor auxiliaries
5. Interconnecting power and control wiring
6. Fan dampers, tunnel dampers and controls
7. Sound attenuators
8. Local instrument panels
9. Miscellaneous appurtenances

B. The Work includes the following:

1. Furnishing, testing, and installing tunnel ventilation equipment identified as emergency or tunnel ventilation fans, smoke exhaust fans, dampers, sound attenuators and associated appurtenances for complete operating tunnel ventilation system. All work shall comply with NFPA 130 and shall be in accordance with local codes. If necessary, fans shall be installed in sections to accommodate transfer to fan room.

C. The Work also includes the following:

1. Submitting for approval working drawings indicating the size and location of each concrete foundation for the axial fans, reinforcing bar requirements for these foundations and the expected static and dynamic forces and moments generated by the equipment.

2. Furnishing and installing reinforcing bars, dowels and concrete required for the construction of the equipment foundations.

3. Furnishing and installing anchor bolts and anchor bolt details indicating the type, size and location of anchor bolts required for the installation of the fans and accessories, dampers and ductwork.

4. Submitting for approval terminal-to-terminal working drawings of the electrical power and control interconnections between equipment supplied by this Contractor; power...
and control interconnections to each damper motor; control connections to interface terminal cabinets.

5. Furnishing and installing all the metal ductwork connecting the fan and its accessories, including the ductwork between the fan accessories and the building structure.

6. Furnishing and installing companion flanges and mounting frames shown on Contract drawings. Coordinating hole locations and hole sizes on companion flanges and mounting frames with connecting damper flanges, sound attenuators flanges, ductwork flanges and screen guards.

D. The following definitions apply to the Work of this Section:

1. Fan: The terms fan, emergency fan, tunnel ventilation fan, smoke exhaust fan, and fan assembly are synonymous and are deemed to be a axial flow fan complete with flexible connections, sound attenuators, transition pieces, directly connected reversible or non-reversible motor as appropriate and mounting brackets as required. (Exception: Station smoke exhaust fans shall be intended to operate in forward direction only with non-reversible motors and directional vanes as required, while the emergency fans shall be reversible.)

2. Forward Flow: Airflow generated by the fan in the direction of the fan impeller toward the fan motor. Forward direction of airflow shall be in exhaust mode; exhausting air from tunnels to atmosphere.

3. Reverse Flow: Airflow generated by the fan in the direction of the fan motor toward the fan impeller. Reverse direction of airflow shall be in supply mode; supplying air from atmosphere to tunnels.

4. Pitch: The angle formed by the chord line of a fan blade root cross-section and a line parallel to the direction of rotation.

5. Manufacturer’s Representative: A representative from the firm of manufacturer for each and every category of equipment furnished under this Section.

E. Fan Manufacturer

1. The manufacturer of the fans provided under these Contract Specifications shall be a manufacturer who, for at least 5 years, has been regularly engaged in the design, assembly and testing of axial flow fans of the type and capacity not less than that to be furnished under this Contract, and have experience in the design and fabrication of fans capable of operation at 482 degrees F air stream for one hour.

2. All fans provided under this Contract shall be the product of the same manufacturer whose name appears on the theoretical fan performance curves submitted in accordance with Article 1.04.C.1, Submittals – Products Data, herein.

F. Related Sections: The work of following Contract Specification sections is related to the work of this Section.

1. Section 25 60 00, Building Management System.

2. Section 26 24 14, Motor Starters for Tunnel Fire Ventilation Fans.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
B. Air Movement and Control Association (AMCA):
   1. 210 Laboratory Methods of Testing Fans for Certified Aerodynamics Performance Rating (ASHRAE 51)
   2. 301 Methods for Calculating Fan Sound Ratings from Laboratory Test Data
   3. 500D Laboratory Methods of Testing for Dampers Ratings

C. American Bearing Manufacturers Association (ABMA):
   1. 9 Load Ratings and Fatigue Life for Ball Bearings
   2. 11 Load Ratings and Fatigue Life for Roller Bearings

D. American Institute of Steel Construction, Inc. (AISC):
   1. Steel Construction Manual

E. American Iron and Steel Institute (AISI)

F. American National Standards Institute (ANSI):
   1. B46.1 Surface Texture, Surface Roughness, Waviness and Lay, Part 1
   2. C1 Specification of General Requirements for a Quality Program
   3. S12.56 Determination of Sound Power Levels of Noise Sources
   4. S2.19 Balance Quality Requirements of Rigid Motors

G. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE):
   1. 51 Laboratory Method of Testing Fans for Rating
   2. ASHRAE Handbook – Fundamentals

H. American Society of Mechanical Engineers (ASME)
   1. B18.21.1 Lock Washers

I. American Society for Non-Destructive Testing (ASNT)

J. American Society for Testing and Materials International (ASTM)
   1. ASTM A36 Structural Steel
   2. ASTM A123 Zinc (Hot-Dip-Galvanized) Coatings on Products Fabricated from Rolled, Pressed and Forged Steel Shapes, Castings, Plates, Bars, and Strip
   3. ASTM A193 Alloy--Steel and Stainless Steel Bolting Materials for High-Temperature or High Pressure Service and Other Special Purpose Applications
   4. ASTM A194 Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
   5. ASTM A239 Locating Thinnest Spot in a Zinc (Galvanized) Coating on Iron or Steel Articles
6. ASTM A240 Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels and for General Applications
7. ASTM A276 Stainless and Heat-Resisting Steel Bars and Shapes
8. ASTM A388 Practice for Ultrasonic Examination of Heavy Steel Forgings
9. ASTM A588 High Strength Low Alloy Structural Steel
10. ASTM A666 Annealed or Cold Worked Austenitic Stainless Steel, Sheet, Strip, Plate, and Flat Bar for Structural Applications
11. ASTM B247 Aluminum and Aluminum-Alloy Die, Hand and Rolled Ring Forgings

K. American Welding Society (AWS):
   1. AWS D1.1 Structural Welding Code, Steel
   2. AWS D1.3 Structural Welding Code, Sheet Steel
   3. AWS D14.6 Welding of Rotating Elements of Equipment

L. International Building Code (IBC)

M. Insulated Cable Engineers Association (ICEA)

N. Institute of Electrical and Electronic Engineers (IEEE):
   1. IEEE 112 Standard Test Procedure for Polyphase Induction Motors and Generators

O. National Electrical Manufacturers Association (NEMA):
   1. NEMA ICS Industrial Controls and Systems
   2. NEMA ICS 2 Industrial Controls Devices, Controllers and Assemblies
   3. NEMA MG1 Motors and Generators

P. National Fire Protection Association (NFPA):
   1. NFPA 91 Exhaust Systems for Air Conveying of Vapors, Gases, Mists, and Noncombustible Particle Solids
   2. NFPA 130 Standard for Fixed Guideway Transit and Passenger Rail Systems
   3. NFPA 221 Fire Walls and Fire Barrier Walls
   4. NFPA 255 Standard Method of Test of Surface Burning Characteristics of Building Materials (UL 723)

Q. Steel Structures Painting Council (SSPC):
   1. SP-3 Power Tool Cleaning
   2. SP-6 Commercial Blast Cleaning
   3. PA-1 Shop, Field, and Maintenance and Painting
4. PA-2 Method for Measurement of Dry Film Thickness with Magnetic Gages

R. Sheet Metal and Air Conditioning Contractors National Association (SMACNA)
   1. SMACNA Industrial Duct Construction Standards

S. Underwriters Laboratories (UL)
   1. UL 508 Industrial Control Equipment

1.03 GENERAL REQUIREMENTS

A. Design Criteria:
   1. Fans, attenuators and motorized dampers are a critical component of the tunnel emergency ventilation system and smoke exhaust system. The requirements given herein are designed to ensure that the equipment will function when needed.

   2. The ventilation equipment shall be designed for a transit subway environment. Unusual aspects of this environment include the following:
      a. Dust and dirt from steel wheel and brake wear.
      b. Transient pressure fluctuations from high speed train operations in a subway.
      c. Exposure to combustion products and high temperature air from a fire emergency.

   3. Exposure to air at ambient temperatures and humidity.
      a. Specific criteria values unless otherwise indicated:
      b. Design high temperature: 482 degrees F
      c. Design low temperature: 24 degrees F
      d. Transient pressure fluctuations due to train operation: Plus 16 inches water gage (w.g.) to minus 16 inches water gage (w.g.)

B. Seismic Criteria:
   1. In accordance with IBC.
      a. Occupancy Category: IV
      b. Site Class: C
      c. Ss(g): 1.4
      d. S1(g): 0.48

C. Clearance Limitations
   1. The Contract Drawings indicate the fan room in which the emergency fans, smoke exhaust fans and accessories shall be installed and the clearances of openings and passages through which the components shall be moved for installation and removal in the future. These dimensions shall be field verified by the Contractor.
2. The emergency fans, smoke exhaust fans and accessories shall be provided of such size and arrangement that they will pass through the openings and passages available for the purpose. The Contractor shall provide supports and bracing as required during handling and erection.

D. Handling of Materials

1. The Contractor shall be responsible for all damage caused to the structure in the lifting and transferring operations, at no increase in Contract Price or Contract Time.

E. Supervision of Tunnel Ventilation Equipment Installation

1. The Contractor shall provide the services of a qualified erection superintendent who is competent and experienced with the work involved in the installation of ventilation equipment of this type. The erection superintendent shall, at the site, supervise emergency fan and accessory installation and shall be available when the work in connection with the above ventilation equipment installation is proceeding to verify that the work is properly performed.

F. Welding: All components in this Contract requiring welding shall be welded as follows:

1. Code Requirement: Welding shall conform to the requirements of AWS D1.1 and AWS D1.3, and AWS D14.6 as applicable.

2. Welder Qualification: Welders welding on the work of this project shall be qualified in accordance with the requirements of AWS D1.1, Section 5, Qualification.

3. Process: The welding process employed on the work of this project shall be the shielded metal arc process, in accordance with AWS D1.1 and AWS D14.6 as applicable.

4. Welds shall be inspected with non-destructive testing (NDT). Person performing non-destructive testing shall be certified by ASNT. Only personnel certified for NDT Level I and working under or NDT Level II person or persons certified for NDT Level II may perform non-destructive testing.

G. Spare Parts

1. Provide list of recommended spare parts and tool list for fans, dampers and sound attenuators for Sound Transit’s approval.

2. Provide spare parts and tools according to spare parts list and tool list.

3. Provide one spare impeller hub and one complete set of spare blades for each type and size of the fan. Store spare hub and blades in secure storage containers with permanent labels identifying size of the fan, manufacturers and Sound Transit’s Contract Number.

4. Provide one spare motor identical to the motors supplied for each type and size of the motor. Store spare motor in secure storage containers with permanent labels identifying size of the motor, size of associated fan, manufacturers and Sound Transit’s Contract number.

5. Provide any proprietary tool required for maintenance and/or repair or programming operation.

H. Project record documents requirements shall be according to Section 01 78 39,- Project Record Documents.
1.04 SUBMITTALS

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

B. Shop Drawings: Submit fabrication, assembly, erection, and installation drawings. Indicate descriptions, details, dimensions, arrangements, and assemblies, and locations of all fans, housings, sound attenuators, dampers and ductwork. Include foundation and anchorage data.

1. Submit dimensioned drawings of the fans showing duct transitions, sound attenuator assembly layout, supports, and other appurtenances required for installation. Show on shop drawings, point loads at each support point including summary of dead loads, live loads, axial loads, thrust loads, clearance between the fan and structure, and complete installation details. Design the fan supports in accordance with the design criteria in Article 1.03, General Requirements, herein.

2. Submit structural support design calculations, certified by a professional engineer registered in the state of jurisdiction.

3. Submit theoretical motor performance curves, which are either derived from actual performance tests or from analytical data.

4. Submit shop drawings and the test procedures for the pre-production units as a package.

5. Submit shop drawings for dampers.


C. Product Data: Submit manufacturer's product data and certified test reports for each fan, including fan performance curves, sound power ratings, and electrical characteristics.

1. Submit fan performance curves, separate for forward and reverse direction, initially for each type of fan, and finally for fans as part of the manufacturer's fan certification test results. Performance curves for the initial submittal shall be derived from fan model investigation or actual tests and shall be considered reasonably predictive of the actual fan performance. Fan performance curves shall have the following data plotted as ordinates versus cubic feet per minute as abscissa:
   a. Total pressure, inches of water.
   b. Static pressure, inches of water.
   c. Static efficiency, percentages.
   d. Total efficiency, percentages.
   e. Horsepower input to fan.
   f. Kilowatt input to the motor.

2. The following information shall be included with each performance curve:
   a. Project title.
   b. Name of motor manufacturer.
   c. Catalog name and number of motor.
d. Direction of rotation of motor.

e. Speed, rpm.

f. Electrical characteristics.

g. Fan housing diameter.

h. Hub diameter and hub pocket dimension.

i. Number of blades, blade length and blade weight.

j. Fan blade boss dimension.

3. Submit product data for dampers, including frames, blades, linkages, operators, and damper leakage certified data.

4. Submit product data for sound attenuators including housing, Bill of Material and construction.

5. Submit factory and field test procedures for all fans.

6. Submit factory and field test procedures for all dampers.

D. Records and Certificates: Submit certified test reports of the results of all factory tests and field tests for all fans as specified herein; Part 3 - Execution. Include all records and results of impeller assembly tests.

E. Operations and Maintenance Data: Submit manufacturer's operation and maintenance data and instructions, troubleshooting, corrective maintenance for the fan, test criteria and standards, including fan-motor unit disassembly and reassembly instructions in an Operation and Maintenance Manual. Include spare parts and special tools lists, CAD Drawings and Bills of Material for fan, motor, damper and sound attenuator. Operation and Maintenance Data shall be according to Article 1.04.M, Operation and Maintenance Manual, herein.

F. Test Procedures and Reports:

1. Full details shall be submitted of the scheduled tests and the expected duration of all tests. Samples of all test report forms, details of the methods by which the raw test data is to be reduced and expected test results shall be submitted for review and approval before testing can begin on ventilation equipment, furnished under this Contract. No proprietary information is required to be submitted under this Contract.

2. The test report shall identify the name of manufacturer, model numbers, serial numbers, and the last date of calibration of test instrumentation. Documentation shall be furnished to verify that test instruments have been calibrated not more than 6 months prior to the tests.

3. The test report shall include a list of attendees.

4. Certified test results for all fan, motor, sound attenuator, and damper tests shall be submitted within 30 days after the completion of each test. No equipment shall be released for shipment until the acceptance of certified test data. Copies of accepted test procedures, raw data measured results, calculations and all data derived from tests shall be included as part of report. All test data shall be bound in one report. The test report shall be indexed and cross-referenced in an easily understood manner. No proprietary information is required to be submitted under this contract.
5. Submit actual performance curves after completion of the fan shop tests and fan motor shop tests.

6. Test points shall be indicated on performance curves.

7. All performance curves shall be plotted to such scales as will make it possible to read the data accurately.

8. The performance curves shall be plotted on graph sheets not less than 8-1/2 inches by 11 inches in size.

9. The report shall contain all the results and conclusions and shall include all performance curves, tables, and data required by Article 1.07, Factory Tests and Inspections.

G. Axial Fans:

1. Fan Theoretical Performance Curves:
   
a. Submit for each size fan (listed in the equipment schedule of Contract Drawings), theoretical fan performance curves as specified below. The performance curves shall cover the entire range of load conditions from free delivery to no delivery at 5-degree increments of blade angle above and below the proposed design blade angle. For emergency fans separate curves shall be furnished for forward and reverse direction and each curve shall be identified accordingly.

b. Plot the following composite theoretical fan performance curves with abscissas as air volume in cubic feet per minute and ordinates as:
   
   1) Fan total pressure in inches of water.
   2) Fan static pressure in inches of water.
   3) Static efficiency in percent.
   4) Total efficiency in percent.
   5) Horsepower input to fan shaft.

c. The system resistance curve shall be plotted on each fan curve for two fan parallel operations as required.

d. The stated performance data for both the forward (exhaust) and the reverse (supply) modes shall be based on the fans operating in parallel in each mode, forward (exhaust) and reverse (supply). On each performance curve sheet following information shall be stated:
   
   1) Name of fan manufacturer.
   2) Name of motor manufacturer.
   3) Fan model number.
   4) Contract designation number.
   5) Number of fans operating in parallel.
   6) Fan operating speed in revolutions per minute.
7) Volume of air delivered in cubic feet per minute.
8) Fan total pressure in inches of water.
9) Fan static pressure in inches of water.
10) Fan outlet velocity in feet per minute.
11) Fan outlet velocity pressure in inches of water.
12) Fan static efficiency in percent.
13) Fan total efficiency in percent.
14) Horsepower input to fan shaft.
15) Air density in pounds per cubic foot. (Performance shall be published for an air density of 0.082 lb./per cubic feet.)
16) Fan hub diameter in inches.
17) Fan housing inside diameter in inches.
18) Fan outlet area in square feet.
19) Number of fan blades.
20) Blade angle setting.
21) Direction of airflow (forward or reverse)
22) Calculated rotational moment of inertia of fan wheel assembly in pounds-feet squared.
23) Acceleration time from standstill to operating speed for each mode of operation, supply and exhaust.
24) Maximum motor amperage to start fan from rest.

2. Submit estimated sound power level in decibels (re: db 10-12 watts) of the fan(s) at the design duty point(s) at the eight octave band center frequencies from 63 Hertz to 8,000 Hertz for both forward and reverse directions.

3. Submit documentation by the manufacturer that they have at least five years of continuous and current experience in transit industry in the design, assembly and testing of axial flow fans of the type and capacity not less than that to be furnished under this Contract, and have experience in the design and fabrication of fans capable of operation without failure at 482 degree Fahrenheit air stream for one hour.

4. List of components to be purchased from other manufacturers, giving name of manufacturer, type and characteristic of each item.

5. Certificate of Compliance signifying that equipment to be furnished under this Contract meets the requirements specified herein.

6. Shop Drawings for fans, motors, fan-motor unit bases, installation drawings, dimensioned drawings for anchor bolt locations, and all additional data required to demonstrate compliance with Contract documents.
7. Actual Fan Performance and Noise Data: After completion of the fan shop performance tests, submit for each of the three design duty points, described in Article 1.04.G.1.a, Axial Fans, herein, performance curves and tables of performance data calculated from factory test data taken at each of the test points for both the exhaust (forward) and supply (reverse) modes. The tables shall consist of numerical values at each of the test points for the following:

a. Volume of air delivery in cubic feet per minute.
b. Fan total pressure in inches of water.
c. Fan static pressure in inches of water.
d. Fan outlet velocity pressure in inches of water (with reference to both the fan discharge area and the diffuser discharge areas).
e. Fan static efficiency in percent.
f. Fan total efficiency in percent.
g. Horse power input to fan shaft.
h. Fan operating speed in revolutions per minute.
i. Air density in pounds per cubic feet.
j. Voltage, current, KW input and power factor of motor.
k. Sound power readings for each of eight octave bands taken in accordance with ANSI S12.56.

1) Note: All data shall be reduced to an air density of 0.082 lb./cubic foot.

8. Actual Performance Curves: Submit, after completion of performance tests, performance curves comparable in every respect to the fan theoretical performance curves, as defined above.

9. All records and results of non-destructive examinations.

10. Working Drawings:

a. Pre-production Fan:

1) Submit (non-proprietary) working (layout) drawings for the pre-production unit. Show and fully dimension details of all components.

2) Submit revised working drawings indicating changes to the pre-production fan unit if initial prototype fan shop tests are unsatisfactory, prior to repeating the fan shop tests.

b. Production Fan Unit(s):

1) Submit (non-proprietary) working drawings for the full size fans and accessories.

2) Show and fully dimension details of all components including the following:
a) General arrangement drawing showing fan unit fully assembled.
b) Fan housings showing maintenance and assembly.
c) Inlet and outlet transitional ducts.
d) Straightening vane details.
e) Inlet screens, indicate net free area.
f) Fan rotor and blade assembly.
g) Fan isolation base.
h) Fan bearings.
i) Anchor bolts.
j) Motor and motor enclosure.
k) Fan nameplates.
l) Fan number plates.
m) Flexible connectors.
n) Submit data on fan bearing lubricant.
o) Concrete foundations.

3) Indicate the weight of each removable maintenance section, removable half of the fan housing, the motor, each fan wheel assembly, each inlet and outlet diffuser and the entire weight of the assembled fan.

4) Indicate the size, length, spacing and type of welds.

5) Detail non proprietary working (layout) drawings in accordance with the requirements of the following AISC Publication:
   a) Steel Construction Manual.

6) Show the size and location of holes for bolting the fan housing to the isolation base anchor bolts.

7) Indicate for the fan/motor unit vibration amplitudes, unbalanced radial forces and thrust forces at each motor bearing.

H. Fan Motors:

1. Theoretical Fan Motor Performance Curves:
   a. Submit theoretical fan motor performance curves at rated voltage and speed as specified below.
   b. The fan motor performance curves shall be as follows:
      1) Composite curve plotted with abscissas as horsepower output from no load up to 125 percent full load and ordinates as:
a) Current in amperes.
b) Efficiency in percent.
c) Power factor in percent.

2) Composite curve plotted with abscissas as speed in revolutions per minute from standstill to the synchronous speed of motor and ordinates as:
   a) Motor current in amperes.
   b) Motor torque in pound-feet.
   c) Power factor in percent.
   d) Fan input torque in pound-feet.

3) Temperature Test: Time in minutes as abscissa versus temperature rise in degrees Fahrenheit as ordinates when operated at full voltage and speed.

4) Insulation Resistance - Temperature Load Test. Test result values shall be plotted on semi-logarithmic graphs, the insulation resistance values as logarithmic ordinates and the temperature values as uniform abscissa.

5) Also, for comparison purposes, a curve indicating the safe operating value of insulation resistance shall be plotted on the same sheet with the insulation resistance-temperature test curve.

6) On each theoretical fan motor performance curve sheet shall be stated the following information:
   a) Project title.
   b) Name and address of Contractor.
   c) Fan designation number.
   d) Name and address of motor manufacturer.
   e) Motor type.
   f) Motor number designation
   g) Motor frame size
   h) Motor nameplate horsepower rating.
   i) Nameplate voltage rating.
   j) Nameplate frequency rating and phase.
   k) Full and no load current.
   l) Locked rotor current
m) Motor torque in pound-feet including locked rotor torque, pull-up and breakdown torque
n) Motor synchronous speed in revolutions per minute.
o) Motor maximum safe operating speed in revolutions per minute.
p) Service factor.
q) Calculated rotational moment inertia of motor rotor in pounds-feet squared.
r) Calculated rotational moment of inertia of fan wheel assembly in pounds-feet squared.
s) Maximum allowed motor starting time to accelerate fan wheel from rest to its operating speed, with damper fully open.


3. Submit shop drawings for fan motors

4. Working (layout) Drawings:
   a. Submit non-proprietary working (layout) drawings for fan motors.
   b. Show and fully dimension details of all components including the following:
      1) Motor frames.
      2) Motor end brackets.
      3) Motor space heaters.
      4) Motor leads.
      5) Motor conduit and junction boxes.
      6) Motor shafts.
      7) Motor bearings, including certified bearing analysis from the bearing manufacturer for each different bearing used.
      8) Motor nameplates.
      9) Weight of each motor.
     10) Submit data on fan motor bearing lubricant.
     11) Motor bearing vibration sensors.
     12) Motor speed sensors/switches.
     13) Motor power and control terminal boxes.

5. Factory Tests: Submit at completion of factory motor testing six certified copies of test results.
I. Fan Dampers and Tunnel Dampers (Parallel Blade):

1. Damper Performance Data: Submit certified performance curves and calculated data. All data shall be based on an air density of 0.082 pound per cubic foot.

   a. Curve plotted with abscissas as approach velocity in feet per minute and ordinate as pressure drop in inches water gauge for damper in the wide open position.

   b. Calculated data indicating the air leakage in cubic feet per minute through damper in the closed position against a pressure differential of from zero through 10 inches of water gauge. Curve plotted with abscissas as pressure differential in inches water and ordinate as the air leakage in cubic feet per minute.

   c. Contractor shall submit certified calculated data determining the torque required to operate the damper under specified air flow in the open position and at the specified pressure differential in the closed position.

   d. On each test data sheet the following shall be stated:

      1) Project Title
      2) Name and address of Contractor.
      3) Name and address of damper manufacturer.
      4) Damper designation number.
      5) Corresponding fan designation numbers.
      6) Air density in pound per cubic foot.
      7) Damper face area in feet squared.
      8) Damper free area ratio in percent.
      9) Number of modules and configuration.
     10) Actuators and jack shaft details.
     11) Wiring Diagram, power requirements and limit switches.

   e. The information above shall be based upon data developed in a shop test(s) on a geometrically similar damper(s) tested in accordance with AMCA 500D.

2. Working Drawings:

   a. Submit (non-proprietary) working drawings for dampers.

   b. Show and fully dimension details of all components including the following:

      1) Frames.
      2) Blades.
      3) Shafts.
4) Linkages.
5) Cranks.
6) Stops.
7) Limit switches.
8) Bearings.
9) Blade edge and jamb seals.
10) Operator Motor and speed reducer.
11) Damper operator support base.
12) Operator Motor and speed reducer nameplates including motor voltage, horsepower, locked rotor amperes, full load amperes, power factor, service factor, phases and frequency.
13) Weight of each damper assembly unit including support legs where applicable.
14) Damper terminal box locations and details.

c. Submit data on lubricant for damper shaft bearings, motor bearings and speed reducers.
d. Submit damper operator and electrical control interconnection drawings.
e. The damper operator manufacturer shall certify in writing that the operator and all the internal components are suitable under the ambient temperature range specified herein.

J. Sound Attenuators

1. Performance test procedures shall be submitted at least two weeks prior to the shop test on the scale model.
   a. Procedure shall show conformance to the requirements of ASTM E477 and shall include a fully dimensioned drawing of the model attenuator.
   b. The procedure shall include theoretical or estimated performance data for dynamic insertion loss, self-noise characteristics and air pressure loss with design airflow in both directions.
   c. A detailed description of the instrumentation and measurement techniques shall be submitted with the procedures.
   d. Upon completion of testing, submit a report that includes the procedures, all raw data, and the results. All the results shall be corrected and presented for an air density of 0.082 pound per cubic foot.

2. Working Drawings
   a. Submit (non-proprietary) working drawings for each unique sound attenuator.
b. Working drawings shall include fully dimensioned details of all components including the following:

1) Overall attenuator dimensions.
2) Reinforcing angles.
3) Gage thickness of all sheet metal and plate components.
4) Internal baffle width and spacing.
5) Connection flanges including bolt hole sizes and spacing.
6) Weldment details.
7) Details of supporting legs for floor mounting.
8) Details of lifting lugs.
9) Actual performance data of dynamic insertion loss in each of 8 octave bands and pressure loss data.

   a) The performance information shall be presented on the shop drawing, at an air density of 0.082 pound per cubic foot and for design air flows in both forward (exhaust) and reverse (supply) directions.

K. Painting Submittals:

   1. Application Instructions: Surface preparation, primer, intermediate and top coat shall be applied in accordance with the requirements of the paint manufacturer's printed paint application instructions. A copy of these instructions shall be submitted.

   2. Paint Samples:

      a. Submit four samples of the specified surface preparation, primer, intermediate and topcoat paint coats applied together on a blast cleaned steel sheet. The paint coats shall be applied shingle fashion to expose each representative coat.

      b. The samples shall be 12 inches square and shall be marked with manufacturer's type and color designation.

L. Certificate of Compliance: A certificate of compliance that all components furnished meet the requirements specified herein shall be submitted.

M. Operation and Maintenance Manual:

   1. Provide according to Section 01 78 23, Operation and Maintenance Data.

   2. The Contractor shall furnish an operation and maintenance manual containing information for each piece of equipment. The following identification shall be inscribed on the cover: the words "OPERATING AND MAINTENANCE MANUAL TUNNEL VENTILATION EQUIPMENT", the name and location of the project, the name of the Contractor, and the Contract number. The manual shall include the names, addresses, and telephone numbers of each Subcontractor furnishing or installing equipment and of the local representatives for each item of equipment. The manual shall have a table of contents and be assembled to conform to the table of contents. The pages shall be legible with large sheets of drawings folded in.
3. The manual shall provide a clear explanation of the theory, operation, and maintenance of the equipment accompanied by photos and schematic, wiring and mechanical assembly diagrams, as required. The manual shall be indexed and cross-referenced in an easily understood manner. The manual shall be loose leaf bound and shall include, but not necessarily be limited to, the following information:

a. Operating instructions.

b. Troubleshooting and fault isolation procedures for on-site level repair.

c. A written procedure for airflow measuring in the field with pitot tube and manometer.

d. Procedures for separately removing and replacing motor, rotor, and blades.

e. Fan removal and replacement procedures.

f. Disassembly and reassembly instructions.

g. A list of the components that are replaceable at the three possible levels of maintenance: on site, Sound Transit’s shop, and the manufacturer’s facility.

h. A test procedure to verify the adequacy of repair work on the fans.

i. A preventive maintenance schedule and instructions for the replacement of all electrical component requiring periodic replacement, and detailed instructions for lubrication of moving parts and monitoring of vibration levels.

j. A preventive maintenance schedule for motor bearing inspection, removal and replacement for each component.

k. A list of parts to be replaced and or testing procedures to determine parts to be replaced after a fan has been exposed to a fire emergency condition with air temperatures through the fan exceeding 482 degrees F. This is intended to allow the fan to be put back in service safely and reliably.

l. A list of special tools provided by the manufacturer.

m. A list of recommended tools and test equipment required to perform all maintenance tasks.

n. Two heavy gauge Mylar templates for each fan, for blade angle setting in the field. Template shall include design, maximum, intermediate and minimum blade angles.

o. Recommended spare parts list for one year’s operation.

p. Interchangeable parts list showing parts common to items of equipment.

q. Equipment manufacturers’ descriptive literature including catalog cuts.

r. Record working drawings.

s. Fan, sound attenuator and damper factory test reports.

t. The latest service bulletins with dates that describe the fan, motor and damper operator manufacturer’s service procedures.
1.05 QUALITY CONTROL

A. Quality control requirements shall be according to Section 01 45 00, Quality Control.

B. Manufacturer’s quality assurance program shall be in accordance with ANSI C1.

C. Training: The Contractor shall make available the services of the manufacturer’s service representative for a period of two 8-hour days to instruct Sound Transit’s personnel on the proper operation, repair, and maintenance of the system.

D. Warranty: The Contractor shall furnish one-year Warranty service on the fan assembly that shall commence from Sound Transit’s acceptance of the tunnel ventilation system and shall continue up to and including the first anniversary of Sound Transit’s acceptance. Warranty service shall include labor and materials to replace all parts supplied under these Contract Specifications that fail in service as the result of a defect in materials, installation, or manufacture.

1.06 QUALITY ASSURANCE

A. Supplier and Installer Qualifications:

1. Ventilation Equipment and Component Manufacturers: Ventilation equipment and components specified in Article 2.01 shall be produced by either the equipment manufacturer or by firms experienced and specializing in the types of components required which comply with these Contract Specifications. Equipment and components shall be standard products of the equipment manufacturer and shall have history of satisfactory operation.

2. Installer: Equipment shall be installed by the equipment manufacturer or its authorized representative, or by a skilled and experienced Subcontractor qualified and specializing in the installation of the specified equipment. The installation Subcontractor shall be approved by the equipment manufacturer.

1.07 FACTORY TESTS AND INSPECTIONS

A. General:

1. The following specifies the factory testing requirements for the Tunnel Ventilation Equipment to be procured under this Contract. All tests described herein shall not preclude any additional standard test normally performed by the manufacturers for similar equipment.

2. The Contractor shall notify in writing of all test dates not less than 14 Days prior to the tests, including the expected duration and sequence of testing.

3. The Sound Transit’s representative may witness any or all tests unless waived by Sound Transit.

4. Observations made during the tests, and test results shall be recorded in an acceptable document form, certified by the Contractor and submitted to Sound Transit for acceptance.

5. All expenses in connection with or incidental to the testing shall be borne by the Contractor.

6. The test procedure specified for each fan shall be in the sequence required to enable subsequent testing to proceed. All ventilation equipment or component thereof, which fails to satisfactorily perform during any test as specified, shall be
7. Submit reports for all factory tests and inspections according to Article 1.04, Submittals, herein.

B. Radiographic Inspections:

1. Radiographic inspection shall be performed of every hub and every blade for every fan-motor unit to be furnished under this Contract in accordance with ASNT. Acceptance criteria for radiographic testing shall be according to applicable ASTM Standards. The x-ray identification number shall be etched or engraved on each blade before assembly of the rotor. Where radiographic inspection cannot be used due to the hub thickness, the Contractor may use ultrasound testing according to ASTM A 388. The certification of visual acceptability and the x-ray procedure shall be submitted for acceptance. The x-ray film and ultrasonic results shall be kept on file by the manufacturer for a minimum of five years.

C. Fan Rotor Over Speed Tests:

1. Each fan rotor assembly manufactured and furnished under these Contract Specifications shall be subjected to an unwitnessed overspeed test at the factory, as specified herein, prior to assembly of the complete fans.

2. Prior to the over speed test, each rotor assembly shall be statically and dynamically balanced by the manufacturer to the required ANSI S2.19 level for residual balance so as to provide 2.5 mil peak to peak displacement at each motor bearing during actual operation as a fan/motor assembly at design speed.

3. After radiographic inspection and after static and dynamic balancing, each completely assembled fan impeller shall be spin tested. Spin testing of individual components, such as blades and rotors, in lieu of testing complete impellers, is not acceptable. Each fan impeller shall be spun at 125 percent of the maximum design operating speed for a period of not less than five minutes. Fan impellers shall be tested in both directions of rotation. Following each spin test, the Contractor shall perform a blade fastener torque check and shall make a visual inspection for loose blades and blade & hub surface defects. Replace defective parts and repeat the test before further testing. Certificates of visual acceptability shall be submitted for acceptance.

D. Fan Motors:

1. Arrange for factory testing of each fan motor size. Tests shall be witnessed and unwitnessed.

2. Fan motors shall be tested according to IEEE Publication 112 and NEMA MG-1.

3. Witnessed Tests:

   a. One motor of each nameplate horsepower rating shall be tested at its rated speed in the presence of the Sound Transit’s technical representative.

   b. Tests shall be as follows:

      1) Tests to obtain actual fan motor performance curves verifying the theoretical fan motor performance curves and other data submitted as specified herein.
2) Tests to obtain values for the following electrical and mechanical characteristics with rated voltage and frequency applied to motor terminals:

3) Full load current in amperes.

4) No load current in amperes.

5) Full load input in kilowatts.

6) No load input in kilowatts.

7) Locked rotor current in amperes.

8) Locked rotor input in kilovolt amperes.

9) Locked rotor torque in pound-feet.

10) Calculated rotational moment of inertia of rotor in pounds-feet squared.

11) Power factor in percent at full load amperes and locked rotor amperes.

12) Motor torque in pound feet

c. A complete test of each motor shall include the following:

1) Performance speed-current and speed-torque tests.

2) Temperature test, full load.

3) Insulation resistance-temperature test shall be taken following heat run, readings being taken in degrees Fahrenheit at one-hour intervals for a period of four hours. Temperature shall be determined by the resistance method.

4) Cold and hot resistance measurement.

5) Dielectric Test: (Voltage to be applied shall be based on the voltage rating of insulation plus 1000.)

6) Motor winding resistances.

7) Motor losses, no load, half load, three quarter load and full load.

8) Vibration test.

4. Unwitnessed Tests:

a. Each of the remaining motors shall be tested at its rated synchronous speed unwitnessed.

b. Tests shall be as follows:

1) Winding resistances.

2) No load current in amperes.

3) Dielectric tests.
4) No load speed.
5) Locked rotor current in amperes.
6) Insulation resistance and winding temperature at time taking insulation resistance.
7) Vibration check.

E. Pre-Production Fan Tests:

1. The manufacturer shall perform factory tests on a pre-production model emergency fan and smoke exhaust fan.

2. The pre-production fan may be furnished as a procurement unit after pre-production testing, if all parts and components are in like new and operating condition. Each unit or component must satisfactorily pass all specified factory tests as described elsewhere herein.

3. Vibration Tests:
   a. Prior to other tests, each fan impeller shall be statically and dynamically balanced and the fan-motor unit shall successfully perform the following vibration tests. Emergency fan-motor units shall be tested for vibration in both directions of rotation.
   b. Each fan-motor unit shall be checked for obviously rough operation. Defective bearings shall be replaced, and the fan-motor unit shall be rechecked before further testing.
   c. Each fan-motor unit shall be tested for vibration. The vibration shall be measured in two radial planes 90 degrees apart (front and rear), and in the axial direction.
   d. Vibration amplitude shall be measured and recorded continuously as the fan-motor unit is accelerated from a stand-still to rated design operating speed, and as the fan-motor unit coasts down from rated design operating speed to a standstill. The amplitude versus frequency chart shall be analyzed by the Contractor to determine the cause(s) of the excessive vibration. Additional testing may be required if measured vibration amplitude exceeds the specified allowance maximum, or if the specified vibration measurements reveal excessive vibration at any frequency other than rated design operating speed. Resonant frequencies shall be determined and shall be demonstrated as not to occur within fan-motor unit operating ranges. The analysis shall be submitted to Sound Transit and the cause(s) shall be corrected prior to initiation of further testing. The acceptable limits of vibration shall not exceed the limits specified herein. Measured maximum vibration shall not exceed peak-to-peak amplitudes of 0.0012 inch for fan-motor units operating at a nominal speed of 1,200 rpm or less.

4. Strain and Stress Tests:
   a. Tri-axial strain gauges shall be applied to two blades per impeller and to the hub of unloaded impeller of the pre-production fan. To accurately measure strains and stresses developed in each rotor, one strain gauge at the root, one strain gauge at the midpoint and one strain gauge at the tip of blades on each side shall be applied on a minimum of two blades. In addition, one
strain gauge shall be applied on the impeller hub for each strain-gauged blade. The strains developed during testing at rated speed shall be continuously monitored and measured. The measured strains produced under the test load shall be used to calculate corresponding stresses. Stresses results shall be submitted for acceptance. The methods of strain measurement and stress calculation shall also be submitted for approval. The Contractor shall submit the manufacturer’s certification that the measured strains and calculated corresponding stresses represent the strains and stresses developed in all other blades of the pre-production fan impeller being tested. Calculated maximum expected stresses, and the design properties of the material used to fabricate the impeller blades and hub, shall also be submitted for approval. The stresses shall not exceed requirements of Article 2.02.D.1, Materials, herein.

b. Natural frequency readings of the fan blades shall be taken and included in the test report. Procedures used to determine natural frequency shall be submitted for acceptance.

5. Performance Tests:

a. The pre-production fan-motor unit that has satisfactorily passed the manufacturer's standard production tests and inspections, including the specified factory tests described elsewhere in this Contract Specification, shall be tested in accordance with the procedures specified in “Laboratory Methods of Testing Fans for Rating”, a joint publication of AMCA Standard 210 (ASHRAE Standard 51) using the Fig. 7 “Outlet Duct Setup” or the Fig. 16 “Inlet Duct Setup”. The setup and procedures shall be submitted for acceptance. Test data shall be recorded on AMCA data forms, or the equivalent thereof as accepted by Sound Transit. Performance test shall be conducted at the design speed of the fan with the same motor that will be used in the production units.

1) The Sound Transit’s Representative will witness the performance test.

b. For the purpose of the performance test, the fan boundaries shall be the fan inlet transition flange and the fan outlet transition flange. The fans shall be tested at the blade angle that shall produce the required design volume of air at the required pressure. This blade angle shall not be at its maximum setting. Total pressure shall be between the plane of the inlet flange and the plane of the outlet flange of the fan.

c. Performance tests shall cover the range of airflow rates from the stall line to free air delivery. Test data shall be recorded at a minimum of eight equally spaced settings of the volume regulator. Performance tests of the pre-production tunnel fan-motor units shall be conducted for both directions of airflow.

d. The performance test shall be used to verify performance of the fan. The performance test shall also verify the requirement that the total efficiency of the fan be not less than 65 percent in the exhaust or forward mode and not less than 60 percent in the supply or reverse mode.

1) In the event that the tests show that the fan-motor units do not comply with the requirements as to characteristics, performance, and efficiency, the fan-motor units will be rejected unless
changes are made therein and tests repeated until the specific requirements are met.

e. No allowance in Contract Price or Contract Time will be made for the delay experienced by the Contractor due to the redesign and repetition of the performance tests required due to the failure to meet the stipulated requirements.

f. Submit fan-motor unit performance curves derived from factory tests verifying the theoretical performance curves previously submitted. Test points shall be indicated on performance curves. The required submittal information is listed in Article 1.04, Submittals, herein.

g. Performance curves shall also be developed from witnessed or unwitnessed test data for blade angles of 5 degrees and 10 degrees above and below the design blade angle.

6. The fan shall be calibrated during testing for airflow capacity versus annulus velocity, at the duty point using laboratory grade pitot tube in the annulus and mounted through the bushings in the fan housing.

7. Record the acceleration time for each rotational direction from standstill to operating speed.

8. Sound Tests:
   a. Free field fan total sound power level test:
      1) Pre-production fan-motor unit which has satisfactorily passed all proceeding tests and inspections specified shall be tested in accordance with ANSI S12.56 to obtain sound power level data at eight-octave band center frequencies from 63 Hertz to 8,000 Hertz.
      2) The test data shall be recorded when operating at or near the design duty points in both the supply and the exhaust modes. Test data shall be submitted for approval in tabular form.
      3) At the fan manufacturer’s option noise test may be carried out concurrently with Fan Performance Test specified herein.

9. Reversal Test:
   a. The pre-production tunnel ventilation fan-motor unit which has satisfactorily passed all the above tests and inspections specified shall be subject to reversal tests. These tests shall be conducted with the AMCA 210 arrangement setup for supply mode performance testing.
      1) The test shall require three cycles of rotation reversal. Cycles of rotation reversal are defined as reversal from one direction of motor impeller rotation to the other direction of rotation, and then back to the first direction of rotation.
   b. The reversal test shall begin with the fan-motor unit operated in the supply direction of airflow for a period of 30 minutes.
   c. At the end of the first 30-minute period of operation in the supply direction of airflow, the motor shall be electrically reversed, with a 45-second time delay
imposed between the interruptions of power and re-energizing of the motor for reversed rotation.

d. After the motor has been re-energized, the fan-motor unit shall be operated in the exhaust direction of airflow for a period of 30 minutes.

e. The test shall be continued, with alternating 30-minute periods of operation in the supply and exhaust directions of airflow, until six single rotation reversals have been performed. At the end of each 30-minute period of operation, the motor shall be electrically reversed, with a 45-second delay imposed between the interruption of power and re-energizing the motor for reversed location.

f. After three cycles of rotation reversal, that is, six single reversals of the direction of motor and impeller rotation have been performed; the fan shall be operated for a period of 30 minutes.

g. At the end of the last 30-minute period of operation, the fan shall be de-energized, and permitted to coast to a standstill.

h. Insulation resistance of the motor windings shall be measured just prior to the start of this reversal test, and immediately after the end of the test. In addition, the temperature of the motor windings and of the motor frame shall be continuously recorded throughout the test. Certification of successful performance of the reversal test and certified test data shall be submitted for acceptance.

10. Run-in Test

a. Each fan shall be operated continuously for a total of 12 hours in the forward mode and 12 hours in the reverse mode, if applicable. During reversal, fan shall be allowed to coast to a standstill, before being restarted in the reverse direction.

11. Elevated Temperature Test

a. One preproduction unit of each type, that has passed all preceding tests, shall undergo an elevated temperature test. The fan-motor unit shall operate at the rated flow and pressure for a period of one hour at 482 degrees F in a closed loop system. The test will be considered a success if the fan-motor unit is still operating at the end of the one hour period. The fan-motor unit used for this test shall not be provided as a procurement unit after the test is completed.

F. Fan Dampers and Tunnel Dampers:

1. Witnessed Tests:

a. The full size damper assembly shall be used for the leakage and deflection tests.

b. A prototype shall be used for the pressure loss tests. Minimum size of the prototype shall be 42 inches high by 42 inches wide clear inside dimensions.

c. All testing shall be conducted in an AMCA registered Independent Testing Laboratory. The testing facility shall be approved by the Resident Engineer.
d. Leakage and pressure drop testing shall be conducted in accordance with AMCA Standard 500D.

e. Instruments shall have been calibrated not more than 180 days prior to the tests.

f. Calibration shall be traceable to the National Institute of Standards and Technology.

g. The Contractor shall conduct tests to determine the following:

1) Leakage at shut off in cubic feet per minute per square foot at 10 inches of water pressure differential across closed damper.

   a) During this test damper blades shall be subjected to the normal closing force applied to the actual damper operation.

2) Pressure drop at 2,000 FPM face velocity, based on inside of frame dimension, when damper is in full open position, in accordance with AMCA 500D.

3) Blade deflection at maximum differential pressure.

h. Elevated Temperature Test

1) One damper module and damper operator combination shall be tested to an elevated temperature of not less than 482 degrees F for one hour. The damper and the operator combination shall be operated open and closed at the beginning of the test period, and every ten minutes thereafter for one hour while the damper and damper operator combination subjected to a temperature of not less than 482 degrees F. At the end of the hour the damper and the damper operator shall be operated and closed for ten cycles. The damper and the operator combination shall operate without failure throughout the entire elevated temperature test. The elevated temperature test may be waived if the damper manufacturer and the damper operator manufacturer can demonstrate that a similar model damper and identical model damper operator combination have passed an elevated temperature test on previous projects.

2. Unwitnessed Tests:

a. Perform factory testing of each damper complete with the damper operator unit and with limit switches (both damper operator limit switches and damper blade limit switches) that will operate the damper when installed.

b. Each damper shall be operated a sufficient number of times to determine adjustments and corrections required and to assure correct operation.

c. Indicated adjustments and corrections as required shall be performed.

d. Contractor shall certify in writing that each damper ready for shipment has successfully passed the above testing.

G. Sound Attenuator Tests:
1. Independent Testing Laboratory tests shall be performed on models that are representative of the units to be supplied. On the model the following items shall be identical in size, construction, and design to those corresponding items on the full size attenuator.

2. Separation distance between baffles (minimum of two baffles required for prototype model).

3. Baffles, acoustic fill, wrapping, and perforated facings.

4. Length of the baffles in the direction of flow (height of the prototype model shall be a minimum of 36 inches).

5. Air velocity and air direction through the channel. The Independent Testing Laboratory test shall demonstrate the Dynamic Insertion Loss and Self-Noise characteristics as well as the pressure loss characteristics in accordance with ASTM E477. Detailed description of the instrumentation and measurement techniques shall be submitted. The Resident Engineer shall be notified two weeks before the performance of the test.

1.08 DELIVERY STORAGE AND HANDLING

A. All equipment shall be delivered to the work site in weatherproof containers, which clearly identify the contractor/subcontractor/installer and the equipment and accessories within the containers. Provide fan unit identification numbers on the containers.

B. Submit a schedule of all equipment deliveries pertinent to the work of this Section.

C. The Contractor shall perform all required storage maintenance in accordance with the respective equipment manufacturers’ instructions and recommendations.

D. Any blade or hub damaged by mishandling shall be replaced by Contractor.

PART 2 - PRODUCTS

2.01 EQUIPMENT

A. Emergency fans

B. Smoke exhaust fans

C. Fan motors

D. Fan motor auxiliaries

E. Interconnecting power and control Wiring

F. Fan dampers, tunnel dampers and associated controls

G. Sound attenuators

H. Local instrument panels

I. Miscellaneous appurtenances
2.02 AXIAL FAN MOTOR UNITS (EMERGENCY FANS AND SMOKE EXHAUST FANS)

A. Performance Requirements

1. Modes of Operation:

   a. Each emergency fan shall be designed to operate continuously and satisfactorily in both forward/exhaust and reverse/supply modes and each smoke exhaust fan shall be capable of operating in one direction (exhaust) only. Two emergency fans will be installed in parallel at each end of the station platform in accordance with the Contract Drawings. Two smoke exhaust fans will be installed in parallel in accordance with the Contract Drawings. All fans shall be suitable for operation either individually or in parallel with the other fan. Operation of the fans individually or in parallel at or near the design duty point shall not cause overloading of the motors. When operating in parallel, the fans shall operate smoothly and with stability throughout the entire operating range at all flows and pressures without stalling. All sensors and controls shall be provided by the fan manufacturer to test, sense and assist operation of the fan and avoid stalling. Provide fans with a non-stalling blade angle from free delivery to shut-off to prevent operation in stall region.

   b. In the exhaust mode, ambient air is drawn through the inlet opening from the subway tunnel and discharged through the open end of the sound attenuator towards the stack. The air temperature will vary between 24 degrees F and 482 degrees F and the air density will range from a maximum of 0.082 pound/cubic foot to that corresponding to the absolute temperature change.

   c. In the supply mode outside ambient air is drawn in through the fan shaft and is discharged into the tunnel. The air temperature will vary from 24 degrees F to 104 degrees F.

   d. The fans shall be capable of withstanding a temperature change from 24 degrees F to 482 degrees F in 10 minutes and continuous operation at 482 degrees F for 1 hour without suffering loss of service of the fan or any of its auxiliaries.

2. Rated Capacities and Efficiency:

   a. Each emergency fan shall be fully reversible.

   b. Each fan unit shall be guaranteed to produce the volumes and pressures as listed in the equipment schedule on the Contract Drawings when operating in parallel, and with an inlet air density of 0.082 lb/ft³.

   c. The total efficiency of the fan shall not be less than 65 percent when operating in the exhaust or forward mode and not be less than 60 percent when operating in the supply or reverse mode.

B. Sound Requirements

1. Sound power level rating shall comply with AMCA Standard 301. Ratings shall have a certified sound power level, based on 10E-12 watts.

2. For the emergency fans the total sound power generated shall be submitted when operating in the forward/exhaust and reverse/supply mode at rated speed and design duty points. For the smoke exhaust fans the total sound power generated shall be submitted when operating in the forward/exhaust mode at rated speed and
design duty point. The total sound power generated shall be submitted for following frequencies.

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C. Design Requirements

1. Clearance Limitations:
   a. The Contract Drawings indicate openings in the fan rooms in which the fans will be installed and the access clearance dimensions through which the fan components can be moved for installation.
   b. The fan sub-assemblies and other components shall be provided in the maximum size and arrangement that will pass through the openings and passages without disassembly, the above sub-assembly sizes shall also permit installation and access within the limited confines of the space available.

2. Configuration Requirements:
   a. The intended installation configuration is shown in the Contract Drawings. The emergency fan unit shall be fully assembled and enclosed in a split case housing with the split along the horizontal or vertical centerline (longitudinal axis). Each fan housing shall be bolted in the field to a stable isolation base and supports.
   b. The intended installation configuration is shown in the Contract Drawings. The smoke exhaust fan unit shall be fully assembled and enclosed in a split case housing with the split along the horizontal centerline (longitudinal axis). Each fan housing shall be bolted in the field to a stable isolation base and supports.
   c. Each emergency fan shall be a horizontal or vertical shaft as shown on the Contract Drawings, single stage, and reversible axial flow type with individually adjustable blades at rest and specially designed for subway tunnel ventilation service. Each fan shall be driven by an internally mounted reversible, totally enclosed air over (TEAO) AC induction motor.
   d. Each smoke exhaust fan shall be a horizontal shaft as shown on the Contract Drawings, single stage, and uni-directional axial flow type with individually adjustable blades at rest and specially designed for subway tunnel ventilation service. Each fan shall be driven by an internally mounted, totally enclosed air over (TEAO) AC induction motor.
   e. The fan housing half along the longitudinal axis shall be removable to simplify fan maintenance. The housing shall have axial bolted joints and shall have a circumferential bolted joint on both ends that will allow removal.
of the one half of the housing. The fan housing shall also be equipped with a maintenance access door located at the top of the blade plane that will allow removal and replacement of or adjustment of the blades without removing of the one half of the housing.

f. There shall be no exposed wiring. Sensing instrument leads shall be enclosed in conduit and prewired from the element to a separate motor junction box and from there to a common terminal box, separate from the power or motor space heater wiring, mounted on the outside of the fan housing. Openings shall be provided in the terminal boxes for the conduits as shown in the Contract Drawings.

g. Flexible connectors shall be clamped to the cylindrical fan housing ends and the matching cylindrical end of the transition duct. The clamps shall be a minimum of 3 inches wide, shall be formed to fit over the flexible connector fabric installed over the diffuser and housing, and shall be two-piece construction joined by bolts that adjust the fit and tension of the clamps.

h. Each fan motor unit shall be equipped with a monitoring system that will sense fan speed, bearing vibrations, bearing temperatures, and motor winding temperatures and provide signals to a common panel in the Electrical Room.

i. All fans shall be furnished with similar bushings located in the identical locations on each fan housing for calibration of airflow capacity cubic feet per minute (CFM) versus annulus velocity pressure (Pv), using a laboratory grade pitot tube in the annulus. Deliver fans with the bushings closed with plugs. The fan manufacturer shall supply one laboratory grade pitot tube and suitable manometer. Include a written procedure for testing the fans in the field with these instruments as a part of the Operating and Maintenance Instructions.

3. Imposed Loads:

a. Each fan and its component parts and appurtenances shall be capable of satisfactorily withstanding the affects of all stresses including stresses and loads caused by reversing the direction of the motor.

b. The fan and motor supports shall be designed to maintain proper alignment of the fan during all static and dynamic loading conditions resulting from flows in both directions.

c. The outlet transition duct and its supports shall be designed to withstand the loading imposed by all forces and at all operating conditions. Supports shall fasten to the floor only.

4. Fan Assemblies:

a. Each fan assembly shall be completely shop assembled and shall include the following:

1) Machined hub for holding blades and suitable for mounting directly on the motor shaft.

2) Individual blades shall be secured to the hub by not less than four bolts per blade, or shall be clamped securely between the two halves of a split hub or between suitably designed and
manufactured clamp plates. Blade bolts, hub bolts or clamp plate bolts shall be readily accessible.

3) Blade thrust collar.

5. Additional Performance Requirements:

a. Fans shall be axial-flow type with single-speed motors, suitable for fully reversible operation where indicated. Emergency fans shall be designed to operate in the forward or reverse direction of airflow, with a capability of starting, stopping, or reversing as described in Article 2.03, Fan Motors, herein.

b. Fans shall be capable of operating continuously at specified design points for forward and reverse flows where indicated.

c. Brake horsepower shall not exceed the nameplate horsepower of the fan-motor while operating in the stable range in either flow direction.

d. Operation of emergency fans and smoke exhaust fans shall be stable throughout a range of pressures one inch w.g. above and below the steady-state design operating point.

D. Materials

1. Impeller hub and blades shall be fabricated of aluminum alloy castings, or forgings (ASTM B 247), or steel (ASTM A588, Grade A) suitable for the specified performance and environment. Fan rotating components shall be designed such that no measured or calculated stress level shall exceed 50 percent of the components materials yield strength at specified performance and environment. Fan blades in each impeller shall not vary in weight by more than 2 percent. Each blade shall be stamped with its accurate weight in pounds to within two decimal points. Blades shall be manufactured from a homogeneous material as specified herein and shall have no cast-in or embedded material of any kind. The pitch of the blades shall be manually adjustable without removing impeller from fan unit.

2. The ratio of the hub diameter to the fan housing diameter shall not be less than 0.35. The hub shall have index marks embossed or engraved to show the design operating blade setting and additional settings for a minimum of five additional increments of stagger angle with not less than two on each side of design blade setting.

3. Fan housings, including motor mounts and motor supports, shall be fabricated of hot-rolled steel. Fan housing shall not be less than 1/4 inch thick steel. Fan housing shall be provided with split joints, bolted with gaskets, suitable for all operating conditions as specified, to facilitate disassembly and removal of motor and rotor without removal of entire fan-motor unit or any part of adjacent ductwork. Welds located in the air stream shall be ground smooth.

4. Flanged rings shall be continuously welded to the outer periphery at each end of the fan housings, or flanges may be rolled as part of the fan housing. Flange thickness shall be not less than fan housing thickness. Flanges shall not be less than 3 inches wide. Flanges shall have punched or drilled holes equally spaced not more than 8 inches on centers to permit adjacent elements to be bolted to the housings.

5. Access doors, with gaskets, in the fan housing shall be provided for easy access to the fan blades and blade locking devices. Access doors shall be of the quick-release type, with suitable latches and hinges. Access doors shall have minimum
dimensions of 12 inches wide by 12 inches high. Access doors sizes and locations shall be selected by the manufacturer. The gasket used to provide airtight access doors shall be suitable for all operating conditions as specified.

6. The rotor assembly shall be fastened to the motor shaft by means of an accepted keyed positive locking device. The rotor assembly shaft shall be an extension of the drive motor shaft.

7. Motor mounts and motor supports shall be designed to support the entire weight of the impeller and the motor, and to maintain the alignment of the fan-motor unit assembly in the specified mounting position and to maintain vibration levels within the specified limits. Motor supports shall be sufficient in number to provide the required strength and rigidity and shall be continuously welded to the motor mount and to the housing. Fan motor and fan rotor assembly shall be totally enclosed within the fan housing and not protrude at either end of the fan housing.

8. Nosepiece cover plates, access doors, and aerodynamic separation plates, and straightening vanes where provided shall be secured by means of positive fastening devices which are fully effective for the required directions of impeller rotation, for all blade settings, and for all conditions of operation specified herein.

9. Fan motor unit assembly supports or braces shall be of carbon steel not less than 3/8 inch thick. Supports for the fans shall include fan motor unit structural steel base with vertical supports extending from the base to the fan housing centerline flange and with horizontal thrust plates extending over the full length of the fan housing.

10. Gaskets shall be provided between adjacent companion flanges of fans, cones, and flexible connection. Width of gasket shall be same as flange width. Gaskets shall be capable of withstanding an ambient temperature of 482 degrees F for a period of one hour without degradation of sealing ability and without emitting toxic or noxious fumes.

11. Sufficient lifting eyes shall be provided on each fan assembly to facilitate on-site installation and removal of the fans. Upper removable section of fan housing shall be provided with at least two lifting eyes suitably located.

12. Bolts shall be not less than 1/2 inch minimum in diameter. All bolts unless otherwise noted shall be Type 316 stainless steel conforming to ASTM A 193, Grade B8M on B8MA. Nuts compatible for use with the above bolts shall be alloy steel conforming to ASTM A 194, Grade 2H. Washers and lock washers used on the fans and components shall be of Type 316 stainless steel.

E. Fan Inlet and Outlet Transition Ducts

1. Fan transition ducts shall be provided as indicated in the Contract Drawings. Transition ducts shall be according to Article 2.06, Sheet Metal Ductwork, herein.

2. Transition Ducts shall be fabricated of hot or cold rolled steel conforming to the requirements of ASTM A36 and shall have companion flanges rolled integrally or continuously welded at both ends.

3. Ductwork transitions for emergency and smoke exhaust fans shall be fabricated in sections as required to facilitate installation or removal from the fan room. Each section shall be fabricated and assembled flanged with a gasket, and bolted together to form an airtight perimeter. Flanges and reinforcing angles shall be continuously welded to each duct or section. Terminating ends of reinforcing angles shall be rounded or beveled.
4. Steel for ductwork reinforcement and section connection flanges shall be structural angles conforming to the requirements of ASTM A36. Angles shall not be less than 3 inches by 3 inches by 1/4 inch thick.

5. Flanges shall have punches or drilled holes equally spaced not more than 8 inches on centers to permit bolting to adjacent components. Holes in flanges shall match the holes in fan flanges, or mating duct work, damper or sound attenuator.

6. Access doors shall be of steel construction and shall be provided in the ductwork where indicated in the Contract Specifications. Each access door shall have a clear opening size not less than 30 inches by 36 inches, unless otherwise indicated in the plans. Access doors shall be provided with not less than 1/4 inch thick silicone gaskets to ensure airtight construction. Access doors shall be provided with bolt type latches, welded full height continuous hinge, handhold bar on top of access door and designed so that one person can open the door.

7. Painting of all carbon steel items inside and out shall be in accordance with Article 2.08, Painting, herein.

F. Nameplates

1. Each fan shall be provided with a stainless steel nameplate permanently stamped with the name of the manufacturer, manufacturer’s identification number, fan type, fan designation number, shop order numbers, serial number of fan, year of manufacturer, maximum safe operating speed of fan in revolutions per minute, fan impeller diameter, first critical speed in revolutions per minute, maximum design operation speed and corresponding volume of air delivered, and total and velocity pressures and density specified. The nameplate shall be securely screwed or riveted to the exterior of fan housing in a conspicuous position.

2. Each fan shall be provided with a stainless steel enamel plate that shall bear, in numerals not less than 3 inches high, the Contract’s fan designation number as indicated on the Contract Drawings. The plate shall be securely screwed or riveted to the exterior of the fan housing adjacent to the fan nameplate.

G. Painting:

1. All carbon steel components including, but not limited to, the entire fan housing inside and out, the duct work including the transition duct and the inlet cone inside and out, on the straightening vanes, nosepieces and the motor supports shall be painted in the shop in accordance with Article 2.08, Painting, herein.

H. Flow Switches

1. The emergency fan system shall be furnished with two flow switches to sense the fan’s mode of operation (forward/exhaust and reverse/supply) as indicated on the Contract Drawings. The smoke exhaust fan system shall be furnished with a flow switch to sense the fan’s mode of operation in forward/exhaust as indicated on the Contract Drawings. Normally open contacts shall be wired to the control junction box.

2.03 FAN MOTORS

A. General:

1. The performance of the fan motors furnished shall conform to the accepted actual fan motor factory test performance curves and other accepted data.
2. Motors furnished shall be designed for satisfactory operation in tunnel atmospheres exposed to excessive moisture, industrial fumes and non-metallic dust. The motors shall withstand long periods of idleness in such conditions without damage or deterioration.

3. Description of Fan Motors: Fan motors provided shall be the motor manufacturer's "energy efficient" type, as defined by NEMA MG-12.58, horizontal face mounted, squirrel cage induction motors, NEMA Design as applicable, designed for continuous operation on alternating current.

4. Qualifications of Motor Manufacturer: Fan motors shall be the product of an established motor manufacturer who has been regularly engaged in the production of motors of the required capacities and whose products have operated successfully for a period of at least five years.

5. Motor Manufacturer: Fan motors shall be manufactured by the manufacturer whose name appears on the theoretical fan motor performance curves and on the other submitted data.

6. Motor Design Criteria:

   a. General: Provide fan motors, which will be powered from Motor Control Centers, conforming to the following:

      1) Motors shall be rated in accordance with NEMA Standards for locked rotor input (kilovolt amperes per horsepower) required meeting the specified performance.

      2) Motor enclosures for the axial fans shall be totally enclosed air over type.

      3) Insulation for the fan motors shall be Class H minimum with a Class F temperature rise when tested at service factor of 1.15 without the air over cooling effect.

      4) Voltage rating shall be 460 volts.

      5) Frequency rating shall be 60 Hertz.

      6) Motor shall be designed for operation with a 3-phase power supply.

      7) Synchronous speed for the emergency and smoke exhaust fan motors shall not exceed 1200 rpm.

      8) Motor efficiency and losses shall be determined and motors labeled in accordance with NEMA MG1 12.58 (IEEE 112, Test Method B or E). The guaranteed efficiency shall not be less than the minimum efficiencies listed in NEMA MG-12.58.2, Table 12-8.

      9) Motors shall be designed for continuous operation at full load with air temperature of 482 degrees F for 1 hour. This is a fire emergency operating condition.

   b. Starting:
1) The axial fans will use soft starters as specified in Division 26, Electrical, Section 26 24 14, Motor Starters for Tunnel Fire Ventilation Fans. The motors shall be designed to accelerate the fans from standstill to the operating speed, while under maximum fan load, at least four times in 1 hour, without thermal damage to the motor, with rated voltage applied to the motor.

2) The motors shall be capable, under the specified operating conditions of accelerating the impeller from standstill to rated rotational speed, in either direction, in not more than 30 seconds after being energized at rated voltage.

3) In addition, the axial fan motors shall be designed for three equally spaced reversals of the fan within one hour of continuous operation. The reversals shall incorporate a 45-second delay between interruption of power and re-energizing of the motor for reversed rotation.

c. Temperature Rise: Axial Fan Motors

1) Temperature Rise: When run continuously for an indefinite period at rated voltage, at design speed, and at the maximum fan load the temperature rise of the insulated windings (above an ambient temperature of 104 degrees F) shall not exceed the values established by NEMA Standard MG1-12.42 for a Class F insulation system of the motors when measured by resistance method, even though the actual insulation system is Class H. The maximum fan load in each case is the maximum horsepower that the fan can absorb under all air flow and/or pressure variations in the stable operating range at the corresponding speed, and not the horsepower absorbed at the operating point corresponding to the pressure specified. With the same continuous operation and loading as above, except with a voltage variation of 10 percent above or 10 percent below the rated voltage, the temperature rise shall not exceed the values established by NEMA MG1-12.42 for a Class F insulation system of the motors when measured by resistance method even though the actual insulation system is Class H.

2) When started four times in 1 hour, as described in Article 2.03.A.6.b, Starting, herein, the motor temperature rise (above an ambient temperature of 104 degrees F) shall not exceed the values established by NEMA Standard MG1-12.42 for the Class F insulation system of the motors when measured by resistance method. The first start shall be with the motor at ambient temperature and any two successive starts may be within a 10-minute period.

3) When subjected to the reversal tests described in Article 2.03.A.6.b, Starting, herein, the motor temperature rise (above an ambient temperature of 104 degrees F) shall not exceed the values established by NEMA Standard MG1-12.42 for a Class F insulation system, even though the actual insulation system is Class H.

d. Locked Rotor Current and Torque:
1) The locked rotor current at rated voltage and frequency shall not exceed the values listed in NEMA MG1.

2) The locked rotor torque shall not be less than 125 percent of the full load torque at rated voltage and frequency.

3) The combined inertia of the fan wheel assembly and the motor shaft shall not exceed the values listed in NEMA MG-1.

e. Noise and Vibration:

1) Motors shall be designed to operate free from excessive hum, whine or vibration at all speeds within the operating range from standstill to 100 percent of rated speed.

2) The maximum motor sound pressure level in decibels (based on 0.0002 micro bar) shall be measured at all speeds between standstill and 100 percent of rated speed at a distance of 3 feet from the motor in a hemispherical free field under no load conditions.

3) The manufacturer shall balance each motor to provide a peak vibration velocity less than 0.15 inch per second at each motor bearing when tested for vibration in accordance with NEMA MG-1 Part 12.

B. Materials:

1. Insulation: The insulation shall be a sealed insulation system suitable for the operating conditions specified above.

2. Cores: Primary and secondary cores shall be built up of fully insulated, separately punched steel plates laminated and rigidly supported in the stator frame or on the rotor.

3. Rotors: Bars and shorting rings in rotors shall be fabricated of low resistance metal. End connections shall be cast or welded or brazed together.

4. Frames: Motor frames shall be fabricated of cast iron or heavy fabricated steel.

5. End Brackets (End Shields): End brackets shall be fabricated of cast iron or heavy fabricated steel.

6. Space Heaters: Space heaters (strip or cartridge type) shall be provided in each motor frame and shall be rated for 120-volt, ac, single-phase operation.

7. Motor Leads: Motor leads shall be insulated stranded copper conductors secured to prevent jarring loose or coming in contact with moving parts. Motor leads shall be UL listed and conform to ICEA requirements based on voltage, current, enclosure rating and maximum enclosure temperature during operation. The motor leads shall be protected with a high temperature fiberglass sleeve from the motor housing to the power junction box on the motor.

8. Motor Conduit and Junction Boxes: Conduit and junction boxes and covers shall be fabricated of cast iron or steel and be located on the outside of the fan housing. Matching surfaces shall be machined and boxes shall be provided with stainless steel screws.
9. Motor Shafts: Motor shafts shall be made of high grade cold rolled steel, with shaft extension carefully machined to NEMA dimensions. Motor shafts shall be of ample size as to ensure rigidity and the satisfactory operation with the additional loads imposed by the impellers.

C. Construction

1. Windings:
   a. The stator windings shall be securely retained in core slots with end connections braced, to withstand the highest torque produced.
   b. Two $100\Omega$, three wire platinum resistance type temperature RTD sensing detectors shall be provided in each stator (phase) winding. The RTDs shall be corona resistant. The detector leads shall be wired internally to a junction box (separate from power or motor heater wiring) mounted on the motor. This "signal" junction box shall contain a terminal block large enough for all of the motor winding RTDs plus the wiring for the flow switches, motor bearing temperature RTDs and vibration sensors. A similar terminal box shall be provided on the outside of the fan housing with factory installed conduit and wire routed to the signal junction box on the motor.
   c. The RTDs shall be connected to a control terminal box on the fan housing for processing. Coordination with the controls contractor will be necessary to ensure that temperature and vibration levels are monitored and alarmed as determined by the motor manufacturer.

2. Insulation:
   a. The sealed insulation system shall be the type wherein the entire stator is impregnated with an epoxy resin.
   b. The epoxy resin impregnation shall be performed after fully insulated stator coils have been wound in core slots of the stator and after end turns have been braced and connections have been made and insulated.
   c. The impregnation by the vacuum pressure process shall consist of multiple submersions of the complete stator in liquid epoxy resin followed by baking for curing.
   d. The impregnation shall be performed in such manner that the epoxy fully penetrates the core slots and coils, including end turns, forming a solid winding encapsulation without air voids.

3. Cores: Slots in individual plates and laminated cores shall be smooth and without burrs that may damage coil insulation.

4. Rotors:
   a. Rotors shall be electrically, statically, and dynamically balanced.
   b. Rotors shall be centrally located in the stator bore and shall be easily removable from motors.
   c. Rotors of motors shall operate safely and without excessive vibration at all speeds up to 125 percent of their maximum operating speed. (For motor vibration requirements, see Article 2.03A.6.e, Noise and Vibration, herein.)
d. Conductivity shall not depend on riveted or bolted connections or on soft solder.

5. Frames:
   a. Frames shall be accurately machined and drilled for end brackets and shall be arranged to rigidly support the primary core laminations.
   b. Faces shall be provided for frames and shall be cast integral with or rigidly secured to the frame.
   c. Self-relieving, anti-corrosive drain plugs shall be provided at bottom of motor frames.
   d. Bolt holes in face shall be jig drilled.
   e. Motor frames shall be provided with removable lifting lugs.

6. End Brackets (End Shields):
   a. The brackets shall be secured such that alignment is not dependent on bolt or dowels.
   b. The brackets shall be provided with the strength and rigidity to withstand the electrical and mechanical stresses induced by full voltage starting and reversing.
   c. The opposite drive end bracket shall be supplied with a coated insulated bearing bore to eliminate damage caused by circulating shaft currents.

7. Space Heaters:
   a. Space heaters shall be of such number and wattage to prevent condensation on all internal motor parts in climatic conditions encountered in the fan chambers. The ambient temperature in the fan chamber could be as low as 24 degrees F.
   b. The heaters shall be energized whenever the motor is not in operation and shall be automatically de-energized whenever the motor is in operation. The heaters shall be energized while motors are in onsite storage.
   c. The space heaters shall operate at 120 volts.
   d. Space heaters shall be provided with leads, terminated in a separate junction box on the motor that are not common to either the power or the signal wires. Furnish a separate terminal box on the outside of the fan housing with conduit between the motor junction box and the fan housing terminal box and factory wire between them.

8. Motor Conduit and Terminal Boxes:
   a. Each axial fan motor shall be provided with separate junction boxes for the power supply wires, the space heaters, and the signal wires (motor winding RTD, vibration monitoring system and fan/motor bearing RTD) on the outside of the fan housing. The boxes shall be stainless steel NEMA 4X.
   b. Boxes shall be of sufficient size to permit the making of all required connections and the entrance of flexible conduits.
c. The location of conduit and junction boxes on motors and the fan housing shall be as shown on the approved working drawings.

9. Motor Shafts:
   a. Shafts shall be constructed of corrosion-resistant high grade cold rolled steel material, and constructed to support and drive fan impeller.

10. Motor Bearings:
   a. Motors shall be equipped with anti-friction bearings. Bearing design shall be based on ABMA 9 or 11, and shall have a minimum L-10 life of 50,000 hours at maximum capacity and maximum speed based on the bearing load imposed by the driven equipment.
   b. Motor bearings shall be constructed of alloy steels and shall be of the ball or roller type and shall be grease lubricated and suitable for continuous operation over the specified speed range.
   c. The bearings for the motors shall be made by one manufacturer and shall be of standard sizes carried in stock by the manufacturer.
   d. The bearing housings shall be of a type to permit disassembly of the motor without exposing or disturbing the bearing elements.
   e. Inner races shall be held on the shaft by a press fit, or shrink fit, such that the shafts are not damaged when bearings are replaced.
   f. The inner race, rolling elements and the outer race of each bearing shall constitute a factory-assembled unit so constructed that the parts cannot be disassembled or interchanged in the field with similar parts of other bearings.
   g. The bearing at one end of the rotor shaft shall provide through its rolling elements for the maximum axial thrust to which it may be subjected.
   h. The bearing at the other end of the shaft shall provide for axial expansion of the shaft by means of a floating outer race.
   i. The bearings shall be supported in cast iron or cast steel housings.
   j. Each bearing housing shall constitute an individual assembly to be bolted to the end bracket in such a way that the motor can be dismantled and the stator removed without having to remove the bearing from the shaft.
   k. Lubrication lines for the motor bearings shall be Type 316 stainless steel and be routed to an accessible area on the outside of the fan housing for ease of maintenance.
   l. The bearing housings shall be designed and constructed for grease lubrication in such a way that the lubricant will not escape along the shaft to the inside or the outside of the motor.
   m. To prevent over-lubrication, an overflow or relief pipe shall be provided which is easily accessible and visible when filling the bearing. The overflow shall be open at all times and so constructed that dirt is excluded without the use of screw caps or other devices to be manipulated by operators.
n. The contractor shall submit for approval the characteristics of the lubricant the motor bearing manufacturer recommends for the bearings for the type of service, given ambient temperatures and the maximum fire emergency temperature condition. The lubricant recommended shall be furnished and applied immediately after construction of the motors in amounts sufficient to provide complete initial lubrication.

o. Each fan/motor bearing shall be furnished with a vibration monitoring system, designed and installed for integration with the remote I/O network. The vibration monitoring system shall be a two-wire, current-loop powered system operating on 4-20 mA base. The velocity sensor shall use solid-state, epoxy-encapsulated circuitry with a piezoelectric crystal and output current proportional to velocity. The system shall have a frequency response range from 10 Hz to 10,000 Hz. The vibration monitoring components shall be designed, constructed, and capable of full operation for 482 degrees F for 1 hour, 100 percent humidity, and blowing rain. Encasements and enclosures shall be NEMA 4X stainless steel including lubrication lines.

1) The manufacturer shall determine "baseline", "alert", and "alarm" vibration level values and include these values in the Operational and Maintenance Data. The alert level shall relate to general wear and/or minor defects indicating that maintenance is required. The alarm level shall relate to dangerous vibration caused by damage and/or sudden out-of-balance conditions.

2) The controls shall be programmed to "alert" and "alarm" vibration levels as determined by the fan/motor/bearing manufacturer.

p. Each fan/motor bearing shall be furnished with a three wire, 100Ω platinum resistance thermal detector (RTD). The RTDs shall be corona resistant.

1) The manufacturer shall determine "baseline", "alert" and "alarm" bearing temperature values and include these values in the Operation and Maintenance Data. The alert level shall relate to general wear and/or minor defects indicating that maintenance is required. The alarm level shall relate to dangerous temperatures caused by damage and/or failure.

2) The controls shall be programmed to "alert" and "alarm" bearing temperature levels as determined by the fan/motor/bearing manufacturer.

11. Motor Nameplates: Each motor shall be provided with two stainless steel nameplates and connection diagrams. Nameplate shall be stamped with the name of the motor manufacturer, the motor horsepower, frame size, voltage, phase, frequency, insulation type, temperature rise, ambient temperature, full load current, locked rotor amperes in addition to indicating code letter, speed in revolutions per minute, motor type, service factor, motor serial number, bearing numbers and shop order number. One nameplate and connection diagram shall be furnished on the motor and the other riveted or screwed to the exterior of the fan housing immediately adjacent to the fan nameplate.

12. Painting: All exterior surfaces of motors shall be painted except for nameplates and machined surfaces to receive appurtenances, in accordance with the requirements specified in Article 2.08, Painting, herein.
2.04 FAN DAMPERS AND TUNNEL DAMPERS

A. General:

1. Dampers shall be the product of a single manufacturer, and like components shall be furnished by a single supplier.

2. Dampers shall be designed for either horizontal or vertical installation as required.

3. Damper sizes shall be understood to signify the dimensions inside the damper frame.

4. Dampers shall have a net free area of not less than 80 percent measured to the inside of the damper frame when damper blades are fully open.

5. Dampers shall be arranged for two blade positions: fully opened and fully closed.

6. Dampers shall be furnished complete with components and incidentals as specified herein; with structural-support elements and hardware required for installation of the dampers and with additional accessories which may be needed in order to meet the performance requirements as provided in these Contract Specifications.

7. Upon loss of electric power dampers shall move to the power-off position (open or closed) as indicated in Contract Drawings.

8. The dampers shall be designed to be readily assembled in the field from modules. Each damper module shall be of the multiple-parallel-blade type, with an independent channel frame; and shall be factory-assembled complete with frames, blades, shafts, bearings, seals, linkage, and intermediate supports, both horizontal and vertical framing members, required at the head, sill, mullion, and jambs of each damper assembly to erect the modular panels into composite dampers which are functional as specified herein.

9. Multiple damper modules may be operated by use of jack shafting.

10. Each damper module shall have integral channel frames with connecting linkage between modules and operators which shall permit the blades in each damper assembly to operate in unison. Modules shall be individually removable from composite assembly.

11. Dampers shall be fabricated in multiple sections where required. Each multiple section shall be match marked with stencils in a conspicuous location for identification at the site. The sections shall be interconnected with bolted splice plates. The sections shall be of such size which can be brought into the installation locations through the access provided and to facilitate handling, erection, and disassembly.

12. Each damper module shall be provided with blade-mounted position limit switches for remote indication of damper position. Two sets of contacts shall be wired in series. One set to indicate damper is fully closed and one set to indicate damper is fully open. A third set of contacts shall be wired in parallel to indicate damper is not fully open for the fail open type dampers and to indicate damper is not fully closed for the fail close type dampers. Terminate damper monitoring circuits in one terminal box.

13. Mullion supports shall be designed by the damper manufacturer. The mullions shall be full length and width and height of the dampers. Mullion supports shall be of galvanized steel, and shall have punched or drilled holes, equally spaced for damper
module attachments. Number of holes and space between the holes shall be selected by the damper manufacturer. Mullion supports shall be installed by the Installing Contractor. The Contractor shall recommend the mullion attachment method for mullion attachment to damper companion flanges and mounting frames and align the equipment with the embedments.

14. Temporary supports and bracing shall be provided to maintain dampers square and rigid at all times during handling and erection.

15. Dampers provided shall be parallel acting, multiple blades, and electric motor operated type, with associated open and close limit switches. The location of damper operators shall be as shown on the Contract Drawings.

16. Damper blade shafts shall be provided with crank arms connected to a linkage bar such that damper blades may be rotated 90 degrees to open or closed position by movement of damper operator arm. Damper blade shaft axis shall be in the horizontal plane. The damper operator shall hold damper blades firmly against stationary stops in the closed position.

B. Manufacturer’s Qualifications: Dampers and damper operators shall be the products of a manufacturer who has not less than five years experience in transit industry in manufacturing dampers and damper operators as specified herein.

C. Damper and Damper Operator Manufacturer: The damper and damper operators shall be manufactured by the manufacturer(s) whose names appear on the submitted data.

D. Design Criteria: Dampers shall be designed to produce industrial, heavy-duty rigid units that will withstand encountered operation, erection and transportation stresses.

1. Temperature Operating Range: Dampers and damper operators for the emergency and smoke exhaust fans shall be capable of satisfactorily operating through the normal ambient temperature range of 24 degrees F to 104 degrees F and under fire conditions for air stream temperatures of 482 degrees F for 1 hour.

2. Damper Blade and Shaft Assembly Deflection: Damper blade and shaft assembly deflection shall not exceed 1/180 of the span length between centers of shaft bearings with damper in closed position while withstanding a maximum combined conditions of pressure differential of 16 inches of water gauge and 482 degrees F or fan shut off pressure whichever is greater.

3. Air Leakage: Back pressure air leakage through the damper assembly shall not exceed 25 cubic feet per minute per square foot of damper face area while in the fully closed position and while withstanding a maximum pressure differential of 8 inches of water gauge.

4. Pressure Loss: Pressure loss through the damper assembly shall not exceed 0.15 inch of water in the fully open position with a maximum face velocity of 2,000 feet per minute.

5. The entire damper installation shall be designed to withstand, with the blades closed, repetitive loading of 83 lbs/sq foot (16 inches water gauge) due to pressure transients applied to either side of the damper.

6. Dampers and their associated structural supporting members shall be capable of withstanding a maximum differential static pressure across the damper of 16 inches water gauge, and a minimum differential static pressure of 6 inches of water gauge for 2,000,000 reversals. Installed dampers shall withstand maximum static pressure caused by fan operation against a closed damper.
7. Linkage Bars:
   a. Linkage bars shall be designed to withstand without exceeding allowable
      limits of deflection twice the maximum operating force of the damper
      operator.
   b. The vertical movement of linkage bars shall be accomplished by the rotation
      of crank arms on damper operators. A turnbuckle linkage adjustment shall
      be provided with each linkage to provide a convenient means of adjusting
      the length of the connecting rod.

E. Material:

1. Damper Frames:
   a. Damper frames for support of damper blade shafts shall be fabricated from
      ASTM A36 structural steel channel sections.
   b. Channel sections shall be not less than 6 inches web. The damper frame
      shall have three inch flange on the mounting side and two inch on the
      opposite side.
   c. Damper frames shall be provided with corner bracing and lifting lugs and all
      joints shall be continuously welded. All welds in the air stream, except fillet
      welds, shall be ground smooth (ANSI 125 in accordance with ANSI B46.1,
      Part I).
   d. Stationary blade stops shall be provided on damper frames, welded in place,
      against which damper blades shall rest when blades are in full open or
      closed position. Stops shall serve to close the space between ends of
      blades and the damper frame without interfering with rotation of damper
      blades.

2. Damper Blades:
   a. Damper blades shall be fabricated from stainless steel sheet conforming to
      the requirements of ASTM A 666, Type 304, Grade A, No. 2B Finish on
      exposed surfaces.
   b. Sheet thickness shall be not less than No.16 United States Standard Gauge
      (USSG).
   c. Damper blades shall be provided with side seals.
   d. Blades shall be airfoil shape and shall be capped at the ends with welded
      seams and joints.
   e. Damper blades shall not be longer than 46 inches.
   f. The width of damper blades measured in the direction of airflow shall not be
      less than six inches and shall not be greater than 12 inches. Damper blades
      in the open position shall not extend beyond the damper frame.
   g. Damper blades shall have metal-to-metal overlap in the closed position.
   h. Blades shall be sealed at all edges by stitch welding and welds shall be
      ground smooth (ANSI 125 in accordance with ANSI B46.1, Part I).
i. Fasteners for attaching blades to shafts shall be stainless steel bolts, nuts and lock washers. Fastener size to be determined by manufacturer.

3. Seals: Blade jam and edge seals shall be flexible stainless steel.

4. Blade Shafts:
   a. Blade shafts shall be full length and shall be provided to support damper blades fabricated from stainless steel rounds conforming to the requirements of ASTM A276, Type 304 or 303, Condition A, Class C conditioning.
   b. Blade shafts shall be not less than 3/4 inch in diameter or square.
   c. Shafts shall be provided with holes for blade fasteners and with machined ends to fit shaft bearings.

5. Shaft Bearings:
   a. Shaft bearings shall be provided to support blade shafts.
   b. Bearing housings shall be cast iron or cast steel. Pressed steel housings are not acceptable.
   c. Bearings shall be flanged type, self-aligning sleeve bearings with self-lubricating carbon graphite cartridges.
   d. Bearing flanges shall be fastened to the outboard side of the damper frames, by four hexagonal head bolts and lock washers.

6. Linkage Bars: Linkage bars shall be Type 304 stainless steel not less than 1/4 inch thick by 3/4 inch wide, end mounted type designed to provide adjustment between blades.
   a. Guided linkage shall be provided to prevent side loading at linkage connections.
   b. Linkage pivots shall be oil impregnated bronze bearings with Type 303 or 304 stainless steel pins.
   c. Turnbuckles shall be stainless steel.

7. Lifting Lugs: Lifting lugs shall be of steel and a minimum of four lugs (2 on each side) shall be provided on each damper frame.

F. Construction:

1. Damper Fabrication:
   a. Dampers and damper companion flanges and damper operator base support shall be fabricated in accordance with accepted working drawings, as specified and as shown on the Contract Drawings.
   b. The work shall be fabricated from new material, free from mill scale, flake rust and mill pitting.
   c. The work shall be formed and finished without distortion to shape and size with sharp angles and lines.
d. All joints in damper frames shall be continuously welded.

e. Metal work bent by shearing or punching cannot be used.

f. Holes shall be punched or drilled for fasteners. Hole spacing for the damper frame flange channels shall be spaced not more than 8 inches center to center and holes shall be equally spaced.

g. Re-entrant corners shall be shaped notch free.

h. Edges of work shall be ground smooth.

i. Brackets, lugs, and similar accessories shall be included as part of the metal work.

j. Damper operators shall be mounted on damper frames on a base support welded to the damper frame. The base support shall be in a horizontal plane after field installation. The support shall be reinforced to prevent deflection of the operator from its normal path when the operator is operating under load.

k. Nameplate:

1) Each damper shall be provided with a stainless steel nameplate stamped with the name of the manufacturer, damper designation number, damper serial number, bearing numbers, and shop order number. The nameplate shall be located in a location conspicuous after installation.

2) Each damper shall be provided with a stainless steel enamel plate that shall bear, in numerals not less than 3 inches high, the Contract’s damper designation number as indicated on the Contract Drawings. The plate shall be securely screwed or riveted to the damper adjacent to the damper nameplate.

2. Damper Operators

a. General

1) The Contractor shall furnish and install the damper operators on damper as shown on the Contract Drawings and as specified herein. Damper manufacturer shall select number of damper operators required for particular damper size, minimum of two damper operators required per damper. All operators shall be electric rotary type quarter turn actuators and shall be identical, except as otherwise specified herein.

2) The operator shall be capable of changing the position of the damper blades from fully closed to fully open, or from fully open to fully closed in not more than 20 seconds. The application of full stall torque shall not damage the motor. The operator shall be capable of maintaining the damper in closed position and opening damper against a pressure differential of 16 inches of water gauge or fan shut-off pressure, whichever is greater.

3) The motor-operators shall be furnished with spring-actuated devices capable of driving the dampers to their “fail-safe” positions within a period of 15 seconds after the operators are
de-energized. The “fail-safe” position of a damper (normally open or normally closed) is defined as the position which the damper assumes when its operators are de-energized. The spring-return devices shall be fully operational as specified throughout exposure to ambient and airstream temperatures of 482 degrees°F for a period of not less than one hour. The fail-safe position of dampers is shown in Contract Drawings.

4) Particular attention is called to the fact that the operators are to be installed in unheated Fan Rooms or locations where each unit and its internal components may be subjected to the ambient temperature range, including both upper and lower limits, specified herein before. The adjustable switches furnished with each unit shall serve to control the crank arm movement as well as to transmit and receive signals over the ventilation control system; therefore, all switches and their contacts shall be rugged and reliable furnishing complete opening and closure, under the full temperature range specified.

5) The damper operator shall be sized for the opening, closing and running torque duty of the damper. The unit shall operate on 120 volts, single phase, 60-hertz power. Damper operator horsepower shall not exceed 1/3 horsepower.

6) The damper operator shall include the motor, actuator unit gearing, position limit switches, torque switches, de-clutch lever, and hand-wheel as a self contained unit.

7) Each damper operator shall be provided with a position indicator, of sufficient size to be visible from the floor, to indicate the damper position.

8) Motor leads and position limit-switches (internal to damper operator) contacts shall be factory-wired to cast iron weatherproof terminal boxes. Terminal box shall be mounted to the motor mounting plates. External limit switches shall be wired to separate weatherproof terminal box. Both terminal boxes shall have tightly-fitting, gasketed covers designed to resist the entrance of dust and fluids, and shall have threaded conduit openings.

b. Motor

1) The motor shall be specifically designed for damper operator service and shall be of high starting torque, totally enclosed, non-ventilated construction. Motor insulation shall be a minimum NEMA Class F, with a maximum continuous temperature rating of 311 degrees F (rise plus ambient) for the duty cycle specified.

2) The motor shall be of sufficient size to open or close the damper at the maximum encountered torque. The motor shall be capable of operating at plus or minus 10 percent of the specified voltage. The motor duty rating shall be sufficient for at least five continuous cycles (open-close-open, or reverse) without exceeding its temperature rating. Motor bearings shall be of the anti-friction type, and permanently lubricated.
3) The motor shall be an independent sub-assembly such that the power gearing shall not be an integral part of the motor assembly, to allow for motor or gear changes dictated by system operation changes.

4) The motor shall be equipped with internal thermal contacts to protect against motor overload.

5) Motors shall be provided with space heaters for 120-volt, single phase operation of such number and wattage to prevent condensation on internal motor parts in all climatic conditions encountered.

c. Lost Motion Device

1) The operator shall have a built-in device that allows the motor to reach full speed before engaging the damper load when required by unseating applications.

d. Manual Operation

1) A metallic hand-wheel not less than 10 inches in diameter shall be provided for manual operation with arrow to indicate "open" rotation. The hand-wheel shall not rotate during motor operation thereby ensuring personnel safety. A seized motor shall not prevent manual operation. When in manual operation mode, the actuator shall remain in this mode until the motor is energized, at which time the actuator shall automatically return to electric operation without imparting any motion to the hand-wheel. Movement from motor operation to hand-wheel operation shall be accomplished by a positive, pad-lockable de-clutching lever, which mechanically disengages the motor and related gearing. It shall be impossible for simultaneous manual and motor operations to occur. Friction type de-clutch mechanisms are not acceptable.

e. Position Limit Switches (Internal)

1) Internal position limit switches for each operator shall be provided for open and closed indication of the damper meeting the requirements of NEMA ICS. These limit switches are in addition to blade mounted external limit switches. Position limit switches and associated gearing shall be an integral part of the damper operator. Limit switch gearing shall be of the intermittent type, made of bronze or stainless steel, grease lubricated, and totally enclosed to prevent dirt and foreign matter from entering the gear train. Limit switch contacts shall be heavy duty and silver-plated with wiping action.

2) Switches shall be field adjustable, allowing for trip points from fully open to fully closed positions of damper travel. They shall not be subject to breakage or slippage due to over-travel.

3) Switch design shall permit visible verification of switch position without disassembly.
4) Switch compartment shall have not less than four independently adjustable single pole, double throw limit switches to permit any desired circuit design.

f. Switch Contact Ratings
1) The position limit switch contacts shall be rated at not less than 5 amperes, 120 volts, 60 Hertz.

g. Control Compartment Heater
1) The control compartment shall be provided with space heaters for 120-volt, single phase, operation of such number and wattage to prevent condensation on internal control compartment parts in all climatic conditions encountered in the damper locations.

h. Construction
1) The operator shall possess the following features: Housing castings shall be high strength aluminum alloys or cast iron. The electrical enclosures shall be rated NEMA 4. All external exposed surfaces and hardware shall be completely anti-corrosive. The operator shall incorporate double reduction-hardened worm and high strength bronze worm gears as prime power transmission elements. Mechanical adjustable stops shall be provided for 90-degree rotation plus or minus 10 degrees. It shall have a built-in mechanical dial position indicator. All switches, motor, and heater shall be pre-wired to terminal strips inside of access cover of actuator allowing for electrical field wiring. Shafts, gears and other rotating components shall be supported on heavy duty, anti-friction bearings to provide the highest possible efficiency.

i. External Wiring Terminal Box
1) Provide each damper with one external wiring terminal box. Provide all necessary interlocking conduits, fittings and wiring within the damper assembly and terminate all wiring in one common terminal box connection to Sound Transit’s external wiring.

j. Lubrication
1) All rotating power train components shall be immersed in grease with provisions for inspection and re-lubrication without disassembly. Lubricants shall be suitable for ambient conditions of minus 20 degrees F to 200 degrees F. Adequate seals shall be provided on all shafting. In addition the lubricant shall provide for continued operation of the motor with air temperature of 482 degrees F flowing over the motor for a minimum of 1 hour.

2) One heavy-duty grease gun with a fully loaded cartridge of the approved grease shall be furnished for each damper operator to lubricate the power train components.

k. Nameplate
1) Each damper operator shall be provided with a stainless steel nameplate and connection diagram. Nameplate shall be stamped with the name of the damper operator manufacturer, the manufacturer’s address, unit model number, the nominal motor horsepower, input voltage, full load current, phase, unit operating time for 90-degree movement of output shaft, locked rotor indicating code letter, maximum output torque, running torque, damper operator serial number, and shop order number. Each nameplate and connection diagram shall be located in a conspicuous position after field installation.

3. Painting:
   a. All surfaces of damper operator, damper operator base, and damper frame stiffeners shall be painted except damper blades, damper shafts, damper nameplate, damper operator nameplates, and machined surfaces to receive appurtenances in accordance with the requirements specified in Article 2.08, Painting, herein.

2.05 FINISHES
A. Refer to Article 2.08, Painting, herein.

2.06 SHEET METAL DUCTWORK
A. General:
   1. These Contract Specifications describe the requirements for furnishing and installing transition ductwork on the inlets and outlets of the emergency fans and smoke exhaust fans, including framing intermediate supports and ductwork access doors, and fairings, as shown on the Contract Drawings and as specified herein.

B. Design Criteria:
   1. Ductwork shall be fabricated in accordance with approved shop drawings, as specified herein and as shown on the Contract Drawings.
   2. Ductwork shall be fabricated in multiple sections. The sections shall be of such size that can be brought into the fan chambers through the access provided; and facilitate handling, erection, and disassembly.
   3. Ductwork shall be stiffened with reinforcing angles to be free from excessive vibration at all fan speeds or pressures within the operating range.
   4. Ductwork shall be designed to produce rigid units to withstand imposed loads encountered during transportation, handling, erection, and operation.
   5. Ductwork shall be designed to be airtight while withstanding a minimum positive or negative pressure differential of 10 inches of water without exceeding allowable stresses or fan shut-off pressure against a closed damper, which ever is higher.
   6. Ductwork shall be designed to withstand a minimum pressure differential of 10 inches of water, positive or negative, without exceeding deflection limitations of L/360 for structural members. "L" is defined as span length.
   7. Access doors shall be of steel construction and shall be provided on both sides of ductwork where indicated. Each access door shall have a clear opening size not
less than 30 inches in width by 36 inches in height. Access doors shall be provided with not less than 1/4-inch thick gaskets to insure air-tight construction.

8. Ductwork, access doors and all gaskets shall be designed to withstand an ambient temperature not less than 482 degrees F for one hour of operation.

9. The ductwork shall be furnished complete with all structural members, supports, legs and mounting plates. The manufacturer shall furnish all supports.

10. Ductwork that passes through fire rated walls shall meet requirements of NFPA 221 and NFPA 91.

11. Duct material and construction shall conform to NFPA 91.

C. Materials:

1. Steel Sheet: Steel sheet for ductwork shall be hot or cold rolled steel sheet conforming to the requirements of ASTM A36 not less than No. 10 USSG.
   a. Fairings shall be fabricated from not less than No. 10 USSG sheet steel.

2. Steel Shapes, Angles, and Plates:
   a. Steel for ductwork and intermediate supports shall conform to the requirements of ASTM A36 with a minimum yield stress equal to 36 ksi.
   b. Steel angles for ductwork reinforcement and companion connections between ductwork and other equipment shall be not less than 3 inches by 3 inches by 1/4 inch thick, unless otherwise indicated on the Contract Drawings.
   c. Corner angles for connecting side sheets of ductwork shall be not less than 1-1/2 inches by 1-1/2 inches by 1/4 inch thick.

3. Lifting Lugs: A minimum of two steel lifting lugs shall be provided on the exterior of each ductwork section.

4. Heat Resistant Sealant: After assembly, all air leaks shall be sealed with a heat resistant sealant formulated to perform at temperatures ranging from -15 to 500 degrees F for continuous operation with an intermittent peak temperature capacity of 600 degrees F.

5. Temperature Resistant Gasket: Temperature resistant gasket shall contain carbon fiber with suitable matrix to perform at 482 degrees F for a minimum of 1 hour. Gasket shall have a minimum width of 3 inches and a minimum thickness of 1/4 inch unless otherwise noted on the Contract Drawings. Gasket shall be installed according to manufacturer’s recommendations.

D. Construction:

1. Ductwork shall be constructed in accordance with SMACNA Industrial Duct Construction Standards.

2. Fabrication:
   a. The ductwork side sheets shall be connected together by welding to corner angles. All seams shall be of the continuous welded types only.
b. The section connections shall be well fitted and the sections shall be bolted together.

c. In addition to structural welds all exposed edges of sheet forming the housing shall be continuously welded.

d. The work shall be fabricated from new material, free from mill scale, flake, rust, and mill pitting.

e. The work shall be formed and finished without distortion to shape and size with sharp angles and lines.

f. Metal work bent by shearing or punching cannot be used.

g. Holes shall be punched or drilled for fasteners. Hole spacing for connection flange angles shall be not more than 8 inches center to center and holes shall be equally spaced.

h. Re-entrant corners shall be shaped notch free.

i. Edges of work shall be ground smooth.

j. Terminating ends of reinforcing angles shall be rounded or beveled.

k. Brackets, access doors, lugs, and similar accessories shall be included as part of the metal work.

l. Steel sheet for ductwork shall be welded to angles with continuous fillet welds at top of leg and at the base unless otherwise indicated on the Contract Drawings.

m. Each ductwork section flange shall be match marked with stencils or embossed in a conspicuous location for identification during installation in the fan chambers.

n. All welding shall be in accordance with the latest edition of AWS Welding Code.

3. Painting: All surfaces of the duct work inside and outside, including the fairings and all supports shall be painted in accordance with the requirements specified in Article 2.08, Painting, herein.

2.07 SOUND ATTENUATORS

A. General:

1. All sound attenuators shall be product of a single manufacturer whose name shall appear on the product and product data.

2. Sound attenuator unit shall consist of shell and attenuator splitters assembled on site to form an overall sound attenuator of the dimensions shown on the Contract Drawings.

3. This portion of the specification describes the requirements for furnishing and installing sound attenuators on the emergency fans and smoke exhaust fans as shown on the Contract Drawings and as specified herein.

4. As a minimum, the sound attenuators shall be square or rectangular in the cross section and length as shown on the Contract Drawings and shall be designed for the
design goal specified in Article 2.07.B, Design Criteria, herein. The modules in a
given unit shall be equal to overall length of the sound attenuator.

B. Design Criteria

1. The Contractor shall furnish sound attenuation so that the fan/motor unit and all
auxiliary equipment combined shall be guaranteed not to exceed the following sound
pressure decibel levels when all fans in the fan room are operating simultaneously in
the exhaust mode.

   a. At grade level above the tunnel

   The design goals for noise attributable to fans shall be according to following
requirements.

<table>
<thead>
<tr>
<th>District of Sound Source</th>
<th>District of Receiving Property Within the City of Seattle</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Residential (dBA)</td>
</tr>
<tr>
<td>Residential</td>
<td>55/45</td>
</tr>
<tr>
<td>Commercial</td>
<td>57/47</td>
</tr>
<tr>
<td>Industrial</td>
<td>60/50</td>
</tr>
</tbody>
</table>

Notes:

1. The noise level limits are presented for (daytime)/(nighttime). Daytime is
7 a.m. to 10 p.m and nighttime 10 p.m. to 7 a.m.

2. For intermittent noise sources add 10 dB. Intermittent noise is defined as
a noise that lasts for a cumulative period of less than 10 minutes every
hour.

3. The noise limits shall be reduced by 5 dBA if the noise has pure tones or
contains an audible screech, whine, or hum, or contains information
content such as music or public address system announcements.

2. All acoustical treatment of the fan assemblies is required to meet the above limits,
including, but not limited to, the fan housing external acoustical insulation and outlet
duct silencers supplied by the Contractor.

C. Performance

1. For the sound attenuators shown on the drawings of the emergency fans and smoke
exhaust fans, the minimum dynamic insertion loss with airflow in the exhaust mode
shall be as indicated on the Contract Drawings.

   a. At an air density of 0.082 lbf/ft3, the pressure losses with design flow shall
not exceed values shown in equipment schedules.
2. The self generated sound of any module corrected for face area adjustment factors shall not be greater than the sound power level of the fan unit minus the dynamic insertion loss of the element in any octave band.

3. Independent Testing Laboratory tests shall be performed on scale models that are representative of the units to be supplied. See Article 1.07, Factory Tests and Inspections, herein, for a description of the required shop testing.

D. Materials

1. Sound attenuator shell is defined as a site or factory assembled sheet metal casing into which splitters are installed on site. The shells of the silencers shown on the Contract Drawings shall be fabricated from not less than No. 10 USSG ASTM A240, Type 304 stainless steel.
   a. Flanges and stiffeners shall be of not less than 1/4-inch Type 304 stainless steel bent plate or ASTM A276 stainless steel angles.

2. All splitters including the nose and tail and the face sheets shall be fabricated from not less than 18 USSG ASTM A293 or ASTM A240, Type 304 stainless steel perforated as required to provide acoustic transparency.

3. The filler material shall be inorganic mineral or glass fiber of sufficient density to obtain the required acoustic attenuation. The material shall be inert, vermin-proof and resistant to high humidity conditions. The combustion rating of the material, when tested in accordance with NFPA 255/UL Standard 723, shall not be greater than the following:
   a. Flame Spread Classification 20
   b. Smoke - Developed Rating 20

4. The filler material shall be protected with glass fiber cloth and stainless steel screen.

5. Noses directly exposed to rain and snow shall have no perforations.

6. All components and the entire assembly shall be capable of maintaining its structural integrity and air flow capacity at air flow temperatures of 482 degrees F for one hour.

E. Construction:

1. The sound attenuators shall be constructed in accordance with SMACNA Industrial Duct Construction Standards. Shells shall be sufficiently modularized to allow for ease of disassembly, installation, and reassembly. Sound-attenuators shall be furnished with flanges with minimum of 3 inches width at both ends, to permit the units to be rigidly bolted to adjacent components. Flanges shall be bolted to the outer periphery of the casings unless otherwise indicated. All longitudinal seams shall be of the continuous welded types only. All angles shall be mechanically fastened at corners. Gaskets or sealants shall be capable of withstanding an ambient temperature of 482 degrees F for a period of 1 hour without degradation of sealing ability.

2. The construction shall be for a minimum positive or negative pressure differential of 10 inches of water gauge or fan shut-off pressure against a closed damper, which ever is higher without exceeding allowable stresses.

3. Sound-attenuating modules shall be designed to be readily disassembled and reassembled in the field. Sound-attenuators shall be designed to be capable of
operating and performance requirements specified herein, when the elements are
disassembled and reassembled in accordance with the explicit, written instruction of
the manufacturer of the elements.

4. The sound attenuators shall be furnished complete with all structural members,
supports, legs and mounting plates. The manufacturer shall furnish all floor
supports. Structural supports shall be designed to be bolted to shells. The Contractor
shall provide clips, fasteners, and sealing material for sealing the attenuator to the
wall openings where applicable.

5. The structural members shall be made of minimum 1/2-inch ASTM A240 bent plate
or ASTM A36 carbon steel structural shapes and hot-dip galvanized after fabrication.

6. All welding shall be in accordance with the latest edition of AWS Welding Code.

7. The sound attenuators shall be installed in accordance with the installation
procedures provided by the manufacturer.

F. Nameplates:

1. Each sound-attenuator unit shall be provided with a stainless steel nameplate
permanently stamped with the name and address of the manufacturer, Contractor's
identification number, model type, shop order number and serial number, and Sound
Transit's attenuator designation number. The nameplate shall be securely attached
to the exterior of the attenuator unit in a conspicuous location.

2. The forward direction of airflow shall be permanently marked on each sound
attenuator module in a location conspicuous after installation.

2.08 PAINTING

A. Materials:

1. General:

a. This Section describes the requirements for furnishing and applying paint on
tunnel ventilation equipment as specified herein.

b. The Work includes shop painting the surfaces specified in the several
specification Sections herein.

c. All paint material provided shall be from one source.

d. All paint material shall be Volatile Organic Compound (VOC) compliant.

e. Paint/finishes shall be factory-applied and shall be certified by the
manufacturers of the finishing materials to be capable of withstanding
exposure to an ambient temperature of 482 degrees F for a minimum of one
hour without producing smoke or toxic fumes.

f. Paint colors shall be as selected by the Resident Engineer.

g. Machined surfaces not requiring painting shall be provided with a coating of
suitable anti-corrosion compound before leaving the place of manufacture.

h. Galvanized sheet metal shall not be painted.

2. Primer paint material shall be Carboguard Carbozinc 11HS, a high solids inorganic
zinc rich primer or acceptable substitute.
B. Construction:

1. Surface Preparation:
   a. Surfaces except Surfaces of Motors
      1) Surfaces, except surfaces of motors, to receive primer paint material shall be prepared in accordance with the requirements of SSPC SP-6.
      2) The minimum height of profile after completion of blast cleaning shall be 1.5 mils.
   b. Surfaces of Motors: Surfaces of motors to receive primer paint material shall be prepared in accordance with the requirements of SSPC SP-3.

2. Number of Coats: Surfaces specified to receive paint shall receive one coat of primer paint material, one coat of intermediate paint material, and one coat of topcoat paint material.

3. Dry Film Thickness:
   a. Primer: The minimum dry film thickness of the primer coat shall be 3 mils.
   b. Intermediate Coat: The minimum dry film thickness of the intermediate coat shall be 3 mils.
   c. Topcoat: The minimum dry film thickness of the topcoat shall be 3 mils.

4. Paint Application: Primer, intermediate and topcoat paint materials shall be applied in accordance with the requirements of the paint material manufacturer's printed paint application instructions and in accordance with the applicable non-conflicting requirements of SSPC PA-1.

5. Coating Thickness Measurement:
   a. As specified herein, the applied and cured paint film shall be tested to determine the dry film thickness.
   b. Measurement of dry film thickness shall be in accordance with the requirements of SSPC PA-2.

6. Corrective Painting: Surfaces, which after painting and after installation of components are not as specified, shall be re-cleaned, re-primed and re-painted as may be required until the specified coating requirements have been obtained.

2.09 FLEXIBLE CONNECTIONS

A. General

1. Flexible connections shall be provided where called for on the Contract Drawings. Each flexible connection shall consist of a “flat belt” fabric connector and fabric securing clamps.

B. Materials

1. Fabric shall be suitable for a temperature of 482 degrees F for one hour of operation.
2. The flat belt elastomeric element shall be of gas tight construction, shall have completely sealed edges and shall be devoid of stitching.

3. The fabric material shall be flexible, flame retardant, abrasion resistant, and shall withstand without deleterious effect, saturation with grease and oil.

4. The flat belt element shall be a minimum of 9 inches long.

5. Clamping bars shall be made of 16 USSG Type 316L SS and shall be 3 inches wide. Clamping bars shall have minimum 2 inches by 2 inches by 3/16 inch Type 316L SS angle cleats welded at or near each end.

6. Connection flanges shall be fabricated from structural steel angle sections conforming to the requirements of Specifications for Structural Steel, ASTM A36. Companion angle sections shall be not less than three inches by three inches by 1/4-inch thick. Frame shall be welded with full penetration butt welds. Companion flanges shall have punched or drilled holes sized to receive the size bolts required by component being connected. Companion flanges shall be hot–dip galvanized after fabrication.

7. One end of each section of clamp bar shall be formed to allow for a minimum of 2 inches of overlap.

C. Construction

1. The entire assembly shall be designed to be airtight and shall be of sufficient strength to withstand a pressure of ± 10 inches water gauge or fan shut-off pressure against a closed damper, which ever is higher.

2. Flexible connections shall be designed to allow radial, axial, rotational, and lateral movement of fan housings resulting from expansion, contraction, and dynamics of fan operation, without unnecessary slack in fabric connector material.

3. Flexible connections shall be designed in accordance with SMACNA Industrial Duct Construction Standards.

2.10 COMPANION FLANGES AND MOUNTING FRAMES

A. General

1. Companion flanges shall be provided for connecting dampers, ductwork, sound attenuators and screen guards to concrete floor or concrete wall openings.

2. Mounting frames shall be provided for connecting dampers, ductwork, sound attenuators and screen guards to CMU wall openings.

3. Companion flanges and mounting frames shall be as shown on Contract Drawings.

4. Companion flanges and mounting frames shall be fabricated from structural steel conforming to the requirements ASTM A36. Flanges and frames shall be welded with full penetration butt welds.

5. Companion flanges and mounting frames shall be provided with bolt holes matching to bolt hole pattern of associated dampers, ductwork, sound attenuators and screen guards.

6. Bolts and nuts shall be provided according to Article 2.13, Hardware, herein.
7. Companion flanges and mounting frames shall be hot-dip galvanized. The galvanizing shall conform to ASTM A123 and shall withstand an eight-dip Preece test in accordance with ASTM A239.

2.11 SCREEN GUARDS

A. Screen guards shall be provided where indicated and on tunnel side of tunnel dampers. Screen guards shall be fabricated of not less than No. 10 Stubs Iron Wire Gauge, steel wire. Guards shall have rigid flanges designed to permit the guards to be bolted to the mating companion flanges or to floor or wall openings. Screen guards shall be provided with reinforcement angles with minimum structural angle size of 1 ½ inch by 1 ½ inch by 3/16 inch thick. Mounting and construction shall be designed for a minimum of positive or negative 16 inches water gauge. The guards, including the flanges, shall be hot-dip galvanized after fabrication. Mesh size shall be 2 inches by 2 inches. The galvanizing shall conform to ASTM A123 and shall withstand an eight-dip Preece test in accordance with ASTM A239.

2.12 GASKETS

A. Minimum thickness of gaskets shall be 1/4 inch and width of gasket shall be same as flange width. Gaskets shall be capable of withstanding an ambient temperature of 482 degrees F for a period of one hour without degradation of sealing ability and without emitting toxic or noxious fumes. Gaskets shall be provided at following locations;

1. Between dampers and companion flanges/mounting frames
2. Between ductwork and/or sound attenuators and companion flanges/mounting frames
3. Between wall opening and/or ductwork and sound attenuators
4. Between sound attenuator and flexible connections
5. Between transitions and flexible connections
6. Between transitions and fans
7. Between fans and flexible connections
8. Between transitions and sound attenuators.

2.13 HARDWARE

A. Fasteners:

1. Positive locking devices shall be provided for all nuts and bolts located within the airstream.
2. In accessible areas, fasteners shall be hexagonal head bolts with hexagonal nuts, provided with heavy-duty lock washers.
3. In inaccessible areas, fasteners shall be hexagonal head tap bolts, provided with heavy duty lock washers.
4. Bolts shall be not less than 1/2 inch in diameter unless otherwise indicated.
5. Bolts and tap bolts shall be stainless steel and shall conform to the requirements of ASTM A193, Grade B8M or B8MA, equivalent to AISI Type 316 SS, with suitable lock washers.
6. Nuts for use on the axial fans shall be stainless steel and shall conform to the requirements of ASTM A194, Grade 2H, equivalent to AISI Type 316. Nuts for low torque sealing application and at connecting flanges between ductwork sections or for connecting duct work to sound attenuators and dampers, shall be ASTM A194, Grade 8M, Type 316 SS.

7. Lock washers shall be stainless steel, equivalent to AISI Type 316 and shall conform to the requirements of ASME B18.21.1.

B. Anchor Bolts:
   1. Anchor bolts shall be Type 316 SS Hilti Kwik Bolt II, Rawl-Stud, Maxi-Bolt, or approved equal and shall be fitted with recommended lock washers.
   2. Anchor bolts shall conform to the requirements of ASTM A193, Grade B8M or B8MA, equivalent to AISI Type 316 SS.
   3. Anchor bolts shall not be less than 5/8 inch in diameter.

C. Supports:
   1. Design equipment and ductwork supports capable of supporting combined operating weight of supported equipment and connected systems and components.
   2. Design seismic supports according to criteria shown in Article 1.03, General Requirements, herein.
   3. Obtain approval for support design from Sound Transit.
   4. Fabricate and install supports as required for the application and as shown in Contract Drawings.
   5. Steel supports shall be fabricated from structural steel conforming to ASTM A36.
   6. Supports shall be hot-dip galvanized. The galvanizing shall conform to ASTM A123 and shall withstand an eight-dip Preece test in accordance with ASTM A239.
   7. Submit support calculations according to Article 1.04, Submittals, herein.

2.14 ELECTRICAL REQUIREMENTS INCLUDING CABLES AND CONDUITS

A. Refer to Division 26, Electrical.

PART 3 - EXECUTION

3.01 CONSTRUCTION METHODS

A. General:
   1. These Contract Specifications describe the requirements for installation of the emergency fan and smoke fan assemblies in the fan room as shown on the Contract Drawings and as specified herein.
   2. The work includes installation of the emergency fans, smoke exhaust fans, fan motors and associated adjustable fan-motor auxiliaries, fan dampers, bypass dampers and tunnel dampers, ductwork, sound attenuators, and checking the balancing of fan wheels after installation.
3. The work also includes providing at the site the services of an erection superintendent as specified in Article 1.03.C, General Requirements, Supervision of Tunnel Ventilation Equipment Installation, herein.

4. The erection superintendent shall supervise the installation of the ventilation equipment and shall be present when portions of the work of installation of ventilation equipment are in progress.

5. Field testing of tunnel ventilation equipment shall be performed under the supervision of the erection superintendent.

B. Methods:

1. Lubrication: The lubricant recommended shall be furnished and applied immediately after installation to all components, requiring lubrication in amounts sufficient to provide complete initial lubrication.

2. Fan Impellers: Fan impellers for the emergency and smoke exhaust fans shall be balanced by the Contractor to provide less than 2 mil peak to peak maximum vibration displacement at each fan bearing at all speeds up to and including the maximum design operating speed.

3. Fan Housings:
   a. Install fan housings in accordance with accepted working drawings. Housing alignment work shall be square and true.
   b. Install bolts where shown and where necessary for fastening work in place.

4. Fan Dampers and Tunnel Dampers:
   a. The damper operator and hand wheel shall be in an accessible location to facilitate manual operation and routine maintenance.

5. Ductwork:
   a. Install ductwork between dampers and sound attenuators and outlets of the emergency fans and smoke exhaust fans and sound attenuators as shown on the Contract Drawings.

6. Electrical Cable and Conduits:
   a. Install interconnecting power and control wiring and raceways in accordance with accepted working drawings.
   b. Installation methods shall be in accordance with the requirements specified in the appropriate Sections of these Contract Specifications.

7. The motor space heaters shall be energized within 24 hours after the fans and the damper operators are delivered to a temporary storage place if the installation site is not ready. For fans waiting permanent power on site, temporary power shall be provided to the space heaters.

3.02 FIELD TESTING AND TRAINING

A. Description:

1. These Contract Specifications describe the requirements for field testing of the tunnel ventilation equipment installed and training as specified herein.
2. Field testing shall be performed when permanent electrical power and local controls can be provided for testing. Field testing of the tunnel ventilation equipment shall be performed after field testing of soft starters for fans and for fan damper control panels (FDCP) is complete as specified in Section 26 24 14, Motor Starters for Tunnel Fire Ventilation Fans, and Section 25 60 00, Building Management System.

3. The Contractor shall notify the Sound Transit's representative in writing of all test dates not less than 14 days prior to tests, including the expected duration and sequence of testing.

4. Field testing shall not be performed without the presence of the Sound Transit's representative, unless waived.

5. Axial fans, fan motors, motor controllers, dampers, and associated monitoring and control equipment shall be tested as specified herein.

6. Electrical energy required for field testing shall be furnished by the Contractor.

7. Field testing shall be provided at the expense of the contractor. Tests that fail shall be repeated upon corrections of all deficiencies as often as required until satisfactory performance is demonstrated, at no increase in Contract Price or Contract Time.

8. Field testing of tunnel ventilation equipment shall be performed under the supervision of the Manufacturer's Representative with expertise in the field testing.

9. The Contractor shall provide the accepted field test instrumentation. After field testing is completed and accepted by Sound Transit's representative, the field test instrumentation shall remain the property of the Contractor.

10. A copy of all tests and checks performed in the field, complete with meter readings and recordings, where applicable, shall be submitted for approval.

11. Provide calibration certificates for all field instrumentation used during testing. Calibration shall have taken place not more than 180 days prior to the tests. Calibration shall be traceable to the National Bureau of Standards.

B. Materials: Lubricants of the correct type and grade shall be provided where required.

C. Testing Requirements for the Emergency Fans, Smoke Exhaust Fans and Dampers:

1. Damper Tests:
   a. Each fan damper and tunnel damper shall be subject to rotation reversal tests. A cycle of rotation is defined as reversal from fully open to fully closed position, and then back to fully open. Each damper shall require five cycles of rotation.
   b. After completion of reversal tests, each damper operator shall be de-energized and checked to ensure that it is driven to its "fail-safe" position within 15 seconds after being de-energized.

2. Fan Motor Bearing Vibration and RTD and Winding RTD:
   a. Check that fan motor bearing vibration, fan motor bearing temperature RTD and fan motor winding temperature RTD controls are calibrated and operational for each fan.

3. Fan Vibration Tests:
a. Amplitude and frequency of radial and axial vibration shall be measured, recorded, and checked for conformity to these Contract Specifications. Defective bearings shall be replaced with new bearings and the fan(s) and/or motor(s) rechecked.

b. After above vibration checks have proved successful, check that the fan and motor are fully operational and the entire fan/duct system is ready and cleared for fan operation.

4. Continuous Run Test:

a. Operate each emergency fan individually for a period of one hour and in parallel with each other for a period of 1 hour in the supply and exhaust modes. Winding and bearing temperatures and vibration shall be recorded at 5-minute intervals during each hour of operation. The voltage, current, power factor, power input, and speed shall be recorded for each operating mode.

b. Operate each smoke exhaust fan individually for a period of 1 hour and in parallel with each other for a period of one hour in the exhaust mode. Winding and bearing temperatures and vibration shall be recorded at 5-minute intervals during each hour of operation. The voltage, current, power factor, power input, and speed shall be recorded for each operating mode.

5. Airflow Tests:

a. The Contractor shall use the bushings provided in the fan housing for a pitot tube traverse with a laboratory grade pitot tube. The airflow measurements shall be taken in both supply and exhaust mode of operation for the emergency fans and in exhaust mode for smoke exhaust fans.

6. Starting Test:

a. Each fan shall be started and brought to the rated supply capacity four times in one hour. Each fan shall also be started and brought to the rated exhaust capacity four times in one hour. The starts shall be equally spaced within the hour. The motors shall not overheat nor shall the fans experience excessive vibration during this test.

b. In addition, each fan shall be started in the supply mode and run continuously for 30 minutes at which time it shall be switched to the exhaust mode and run for an additional 30 minutes, following which it shall be immediately switched back to the supply mode, run for an additional five minutes and turned off.

c. The voltage, current, power factor and power shall be continuously recorded. The motors shall not overheat or trip out during the test.

7. Sound Tests:

a. Measure sound pressure level with emergency fans running.

b. Measure sound pressure level with smoke exhaust fans running. Sound testing for smoke exhaust fans shall be performed separately.

c. Note fans that exceed specified sound pressure levels and make recommendation for reducing their sound pressure level to acceptable limits.
d. Sound pressure levels design goals for noise attributable to fans shall be according to Article 2.07, Sound Attenuators, herein.

8. Defects: During the tests, if any defects in equipment, installation, or deviance in initial submittals or analysis become evident, the defects shall be corrected and the tests re-run until satisfactory performance is obtained at no increase in the Contract Price or Contract Time.

9. Tunnel Airflow Tests:

a. The last portion of the field tests shall be the measurement of air movement within the tunnel produced by the ventilation system. These measurements shall serve as a verification that the ventilation system would produce sufficient air movement in the tunnel/train annular area during a fire to satisfy emergency ventilation criteria.

b. These tests shall be performed by qualified personnel (employees of the Contractor or a Subcontractor) who have been approved by the Sound Transit. The overall responsibility for this measurement program shall belong to the Contractor.

c. The Sound Transit shall provide the Contractor with details on three locations for the measurements, the testing conditions (such as ventilation system operating requirements and the location of stopped trains), and the test results required for each location at least 180 days prior to the scheduled date of test initiation. The entire tunnel cross section shall be traversed with a minimum of 36 traverse points in order to measure the average airflow (in cubic feet per minute) through the cross section. The measurements shall be accurate to plus or minus five percent and shall account for the effects of the tunnel portals, changes in horizontal curvature, and location and distance from the stopped train. Contractor shall make the necessary arrangements with the Sound Transit to schedule the tests and to use a stopped train during the actual testing period.

d. Submit to the Sound Transit for approval a written test program at least 45 days prior to the scheduled date of test initiation. This test program shall contain, as a minimum, the resumés of the key personnel participating in the test phase, the specific make and model numbers of the test equipment to be used, and a general procedure to be followed for the set-up of equipment and for the sampling, recording and reduction of the test data.

e. Provide the Sound Transit with the measured test results. If the Sound Transit determines that the measured air velocities are less than the required "cold" air velocities, the Contractor will be notified in writing to increase the blade angles in order to produce the required tunnel airflow velocities. If the increased fan air flows cause overloading of the fan motors, the Contractor shall advise the Sound Transit in writing on the extent of the overload. The Sound Transit shall provide the Contractor with a written list of the appropriate equipment modifications that the Contractor shall be responsible to perform, if any. The field measurements shall then be repeated in order to verify that the required tunnel airflows have been achieved.

f. The Sound Transit shall be notified in writing at least two weeks prior to the initiation of this testing phase in order to coordinate the use of train(s) and to program the appropriate ventilation system operation.
10. Records: Records shall be compiled of the results of all tests. The records shall include defects occurring during testing and corrective measures taken.

11. Training: Provide the services of a factory-authorized service representative to demonstrate the system and train Sound Transit’s maintenance personnel as specified in Article 1.05, Quality Control, herein.

12. Other tests listed elsewhere in these Contract Specifications.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 23 31 13
METAL DUCTS

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes metal, rectangular ducts and fittings for supply, return, outside, and exhaust air-distribution systems in pressure classes from minus 2- to plus 10-inch wg.
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 07 84 00, Firestopping.
2. Section 23 33 00, Air Duct Accessories.

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

1. National Fire Protection Association (NFPA)
   a. NFPA 90A Installation of Air Conditioning and Ventilating Systems
   b. NFPA 90B Installation of Warm Air Heating and Air-Conditioning Systems

   a. ASTM A653 Steel Sheet, Zinc-coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM C920 Elastomeric Join Sealants
   c. ASTM A 36 Carbon Structural Steel

3. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
   a. SMACNA HVAC duct construction standards – metal and flexible
   b. SMACNA Duct cleanliness for new construction

4. Underwriters Laboratory (UL)
   a.) UL 723 Tests for Surface Burning Characteristics of Building Materials

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

B. Shop Drawings: Show fabrication and installation details for metal ducts.
1. Penetrations through fire-rated and other partitions.
2. Duct accessories, including access doors and panels.

1.04 QUALITY ASSURANCE

A. NFPA Compliance:
   1. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
   2. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

PART 2 - PRODUCTS

2.01 GENERAL

A. The sheet metal ducts specified in this section shall not be used in the tunnel ventilation equipment systems.

2.02 MANUFACTURERS

A. In other Part 2, Existing Conditions, Sections where titles below introduce lists, the following requirements apply to product selection:

   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.03 SHEET METAL MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated. Sheet metal materials shall be free of pitting, seam marks, roller marks, stains, discolorations, and other imperfections.

   B. Galvanized Sheet Steel: Lock-forming quality; complying with ASTM A 653/A 653M and having G90 coating designation; ducts shall have mill-phosphatized finish for surfaces exposed to view.

   C. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts.

   D. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.04 SEALANT MATERIALS

A. Joint and Seam Tape: 2 inches wide; glass-fiber-reinforced fabric.

   B. Tape Sealing System: Woven-fiber tape impregnated with gypsum mineral compound and modified acrylic/silicone activator to react exothermically with tape to form hard, durable, airtight seal.

   C. Water-Based Joint and Seam Sealant: Flexible, adhesive sealant, resistant to UV light when cured, UL 723 listed, and complying with NFPA requirements for Class 1 ducts.
D. Solvent-Based Joint and Seam Sealant: One-part, nonsag, solvent-release-curing, polymerized butyl sealant formulated with a minimum of 75 percent solids.

E. Flanged Joint Mastic: One-part, acid-curing, silicone, elastomeric joint sealant complying with ASTM C 920, Type S, Grade NS, Class 25, Use O.

F. Flange Gaskets: Butyl rubber or EPDM polymer with polyisobutylene plasticizer.

2.05 HANGERS AND SUPPORTS

A. Building Attachments: Concrete inserts, or structural-steel fasteners appropriate for construction materials to which hangers are being attached.

1. Use expansion bolt for concrete fasteners for standard-weight aggregate concretes or for slabs more than 4 inches thick.

2. Exception: Do not use powder-actuated concrete fasteners.

B. Hanger Materials: Galvanized sheet steel or threaded steel rod.

1. Hangers Installed in Corrosive Atmospheres: Electrogalvanized, all-thread rods or galvanized rods with threads painted with zinc-chromate primer after installation.

2. Strap and Rod Sizes: Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for steel sheet width and thickness and for steel rod diameters.

C. Duct Attachments: Sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.

D. Trapeze and Riser Supports: Galvanized-steel shapes and plates complying with ASTM A 36/A 36M.

2.06 RECTANGULAR DUCT FABRICATION

A. Fabricate ducts, elbows, transitions, offsets, branch connections, and other construction according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" and complying with requirements for metal thickness, reinforcing types and intervals, tie-rod applications, and joint types and intervals.

1. Lengths: Fabricate rectangular ducts in lengths appropriate to reinforcement and rigidity class required for pressure class.

2. Deflection: Duct systems not to exceed deflection limits according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible."

B. Transverse Joints: Prefabricated slide-on joints and components constructed using manufacturer's guidelines for material thickness, reinforcement size and spacing, and joint reinforcement.

1. Available Manufacturers:
   a. Ductmate Industries, Inc.
   b. Nexus Inc.
   c. Ward Industries, Inc.
C. Formed-On Flanges: Construct according to SMACNA's "HVAC Duct Construction Standards-Metal and Flexible," Figure 1-4, using corner, bolt, cleat, and gasket details.

1. Available Manufacturers:
   a. Ductmate Industries, Inc.
   b. Lockformer.

2. Duct Size: Maximum 30 inches wide and up to 2-inch wg pressure class.

3. Longitudinal Seams: Pittsburgh lock sealed with noncuring polymer sealant.

D. Cross Breaking or Cross Beading: Cross break or cross bead duct sides 19 inches and larger and 0.0359 inch thick or less, with more than 10 sq. ft. of nonbraced panel area unless ducts are lined.

PART 3 - EXECUTION

3.01 DUCT APPLICATIONS

A. Static-Pressure Classes: Unless otherwise indicated, construct ducts according to the following:

1. Supply Ducts: 2-inch wg.

2. Supply Ducts (before Air Terminal Units): 3-inch wg.


7. All Duct connections to the tunnel shafts shall be both a negative and positive pressure: 10 inch wg.

3.02 DUCT INSTALLATION

A. Construct and install ducts according to SMACNA's "HVAC Duct Construction Standards-Metal and Flexible," unless otherwise indicated.

B. Install ducts with fewest possible joints.

C. Install fabricated fittings for changes in directions, size, and shape and for connections.

D. Install couplings tight to duct wall surface with a minimum of projections into duct. Secure couplings with sheet metal screws. Install screws at intervals of 12 inches, with a minimum of three screws in each coupling.

E. Install ducts, unless otherwise indicated, vertically and horizontally and parallel and perpendicular to building lines; avoid diagonal runs.

F. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
G. Install ducts with a clearance of 1 inch, plus allowance for insulation thickness.

H. Conceil ducts from view in finished spaces. Do not encase horizontal runs in solid partitions unless specifically indicated.

I. Coordinate layout with suspended ceiling, fire- and smoke-control dampers, lighting layouts, and similar finished work.

J. Seal all joints and seams. Apply sealant to male end connectors before insertion, and afterward to cover entire joint and sheet metal screws.

K. Electrical Equipment Spaces: Route ducts to avoid passing through transformer vaults and electrical equipment spaces and enclosures.

L. Non-Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls and are exposed to view, conceal spaces between construction openings and ducts or duct insulation with sheet metal flanges of same metal thickness as ducts. Overlap openings on 4 sides by at least 1-1/2 inches.

M. Fire-Rated Partition Penetrations: Where ducts pass through interior partitions and exterior walls, install appropriately rated fire dampers, sleeves, and firestopping sealant. Fire and smoke dampers are specified in Section 23 33 00, Air Duct Accessories.

N. Firestopping materials and installation methods are specified in Section 07 84 00, Firestopping.

O. Protect duct interiors from the elements and foreign materials until building is enclosed. Follow SMACNA's "Duct Cleanliness for New Construction."

3.03 SEAM AND JOINT SEALING

A. Seal duct seams and joints according to SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for duct pressure class indicated.

1. For pressure classes lower than 2-inch wg, seal transverse joints.

B. Seal ducts before external insulation is applied.

3.04 HANGING AND SUPPORTING

A. Support horizontal ducts within 24 inches of each elbow and within 48 inches of each branch intersection.

B. Support vertical ducts at maximum intervals of 16 feet and at each floor.

C. Install upper attachments to structures with an allowable load not exceeding one-fourth of failure (proof-test) load.

D. Install concrete inserts before placing concrete.

E. Install powder-actuated concrete fasteners after concrete is placed and completely cured.

1. Do not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 4 inches thick.
3.05 CONNECTIONS

A. Make connections to equipment with flexible connectors according to Section 23 33 00, Air Duct Accessories.

B. Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for branch, outlet and inlet, and terminal unit connections.

END OF SECTION
SECTION 23 33 00
AIR DUCT ACCESSORIES

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following non-tunnel ventilation equipment. Non-tunnel ventilation equipment is also specified in Section 23 09 00, Instrumentation and Control for HVAC.

1. Backdraft dampers.
2. Volume dampers.
3. Fire dampers.
4. Ceiling fire dampers.
5. Smoke dampers.
6. Combination fire and smoke dampers.
7. Turning vanes.
8. Duct-mounting access doors.
10. Flexible ducts.
11. Duct accessory hardware.

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 23 05 13, Common Motor Requirements for HVAC Equipment.
2. Section 23 05 93, Testing, Adjusting and Balancing for HVAC.
3. Section 23 05 53, Identification for HVAC Piping and Equipment.
4. Section 23 09 00, Instrumentation and Control for HVAC.

1.02 REFERENCES

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

1. American Society for Testing and Materials International (ASTM)

   a. ASTM B221 Aluminum and Aluminum Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
b. ASTM B209 Aluminum and Aluminum Alloy Sheet and Plate

c. ASTM A653/A653M Steel Sheet, Zinc-coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process

d. ASTM A480/A480M General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

2. National Fire Protection Association (NFPA)
   a. NFPA 90A Installation of Air Conditioning and Ventilating Systems
   b. NFPA 90B Installation of Warm Air Heating and Air-Conditioning Systems

3. Underwriters Laboratory (UL)
   a. UL 555 Fire Dampers
   b. UL 181 Factory-Made Air Ducts and Connectors

4. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
   a. SMACNA HVAC Duct Construction Standards—Metal and Flexible

1.03 SUBMITTALS

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

B. Product Data: For the following:
   1. Backdraft dampers.
   2. Volume dampers.
   3. Fire dampers.
   4. Ceiling fire dampers.
   5. Smoke dampers.
   6. Combination fire and smoke dampers.
   7. Turning vanes.
   8. Duct-mounting access doors.
   10. Flexible ducts.

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.
   1. Special fittings.
3. Fire-damper, smoke-damper, and combination fire- and smoke-damper installations, including sleeves and duct-mounting access doors.


1.04 QUALITY ASSURANCE


PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.02 SHEET METAL MATERIALS

A. Comply with SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for acceptable materials, material thicknesses, and duct construction methods, unless otherwise indicated.

B. Galvanized Sheet Steel: Lock-forming quality; complying with ASTM A 653 and having G90 coating designation; mill-phosphatized ducts finish for duct surfaces exposed to view.

C. Stainless Steel: ASTM A 480.

D. Aluminum Sheets: ASTM B 209, alloy 3003, temper H14; with mill finish for concealed ducts and standard, 1-side bright finish for exposed ducts.


F. Reinforcement Shapes and Plates: Galvanized-steel reinforcement where installed on galvanized sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

G. Tie Rods: Galvanized steel, 1/4-inch minimum diameter for lengths 36 inches or less; 3/8-inch minimum diameter for lengths longer than 36 inches.

2.03 BACKDRAFT DAMPERS

A. Available Manufacturers:

1. Air Balance, Inc.

2. American Warming and Ventilating.

3. CESCO Products.

4. Duro Dyne Corp.
5. Greenheck.
7. Prefco Products, Inc.
8. Ruskin Company.

B. Description: Multiple-blade, parallel action gravity balanced, with center-pivoted blades of maximum 6-inch width, with sealed edges, assembled in rattle-free manner with 90-degree stop, steel ball bearings, and axles; adjustment device to permit setting for varying differential static pressure.

C. Frame: 0.052-inch thick, galvanized sheet steel, with welded corners and mounting flange.

D. Blades: 0.050-inch thick aluminum sheet.

E. Blade Seals: Neoprene.

F. Blade Axles: Galvanized steel.

G. Tie Bars and Brackets: Galvanized steel.

H. Return Spring: Adjustable tension.

2.04 VOLUME DAMPERS

A. Available Manufacturers:

1. Air Balance, Inc.
2. American Warming and Ventilating.
3. Flexmaster U.S.A., Inc.
5. METALAIRE, Inc.
6. Nailor Industries Inc.
7. Penn Ventilation Company, Inc.
8. Ruskin Company.

B. General Description: Factory fabricated, with required hardware and accessories. Stiffen damper blades for stability. Include locking device to hold single-blade dampers in a fixed position without vibration. Close duct penetrations for damper components to seal duct consistent with pressure class.

C. Standard Volume Dampers: Multiple- or single-blade, parallel- or opposed-blade design as indicated, standard leakage rating, with linkage outside airstream, and suitable for horizontal or vertical applications.
1. Steel Frames: Hat-shaped, galvanized sheet steel channels, minimum of 0.064 inch thick, with mitered and welded corners; frames with flanges where indicated for attaching to walls and flangeless frames where indicated for installing in ducts.

2. Roll-Formed Steel Blades: 0.064-inch thick, galvanized sheet steel.


5. Tie Bars and Brackets: Galvanized steel.

D. Jackshaft: 1-inch-diameter, galvanized-steel pipe rotating within pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.

1. Length and Number of Mountings: Appropriate to connect linkage of each damper in multiple-damper assembly.

E. Damper Hardware: Zinc-plated, die-cast core with dial and handle made of 3/32-inch-thick zinc-plated steel, and a 3/4-inch hexagon locking nut. Include center hole to suit damper operating-rod size. Include elevated platform for insulated duct mounting.

2.05 FIRE DAMPERS

A. Available Manufacturers:

1. Air Balance, Inc.
2. CESCO Products.
5. METALAIRE, Inc.
6. Nailor Industries Inc.
7. Penn Ventilation Company, Inc.
8. Prefco Products, Inc.

B. Fire dampers: labeled according to UL 555.

C. Fire Rating: Three hours.

D. Frame: Curtain type with blades outside airstream; fabricated with roll-formed, 0.034-inch-thick galvanized steel; with mitered and interlocking corners.

E. Mounting Sleeve: Factory- or field-installed, galvanized sheet steel.
1. Minimum Thickness: 0.052 or 0.138 inch thick as indicated and of length to suit application.

2. Exceptions: Omit sleeve where damper frame width permits direct attachment of perimeter mounting angles on each side of wall or floor, and thickness of damper frame complies with sleeve requirements.

F. Mounting Orientation: Vertical or horizontal as indicated.

G. Blades: Roll-formed, interlocking, 0.034-inch thick, galvanized sheet steel. In place of interlocking blades, use full-length, 0.034-inch thick, galvanized-steel blade connectors.

H. Horizontal Dampers: Include blade lock and stainless-steel closure spring.

I. Fusible Links: Replaceable, 212 degrees F rated.

2.06 CEILING FIRE DAMPERS

A. Available Manufacturers:
   1. Air Balance, Inc.
   2. CESCO Products.
   5. METALAIRE, Inc.
   6. Nailor Industries Inc.
   7. Penn Ventilation Company, Inc.
   8. Prefco Products, Inc.

B. General Description: Labeled according to UL 555C; comply with construction details for tested floor- and roof-ceiling assemblies as indicated in UL’s “Fire Resistance Directory.”

C. Frame: Galvanized sheet steel, round or rectangular, style to suit ceiling construction.

D. Blades: Galvanized sheet steel with refractory insulation.

E. Fusible Links: Replaceable, 212 degrees F rated.

2.07 COMBINATION FIRE AND SMOKE DAMPERS

A. Available Manufacturers:
   1. Air Balance, Inc.
   2. CESCO Products.
4. Nailor Industries Inc.
5. Penn Ventilation Company, Inc.
6. Ruskin Company.

B. General Description: Labeled according to UL 555S. Combination fire and smoke dampers shall be labeled according to UL 555 for 1-1/2-hour rating.

C. Fusible Links: Replaceable, 212 degreesF rated.

D. Frame and Blades: 0.064-inch-thick, galvanized sheet steel.

E. Mounting Sleeve: Factory-installed, 0.052-inch-thick, galvanized sheet steel; length to suit wall or floor application.

F. Damper Motors: Modulating and two-position action.
   1. Comply with requirements in Section 23 05 13, Common Motor Requirements for HVAC Equipment.
   3. Spring-Return Motors: Equip with an integral spiral-spring mechanism where indicated. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size for running torque rating of 150 in. x lbf and breakaway torque rating of 150 in. x lbf.
   4. Outdoor Motors and Motors in Outside-Air Intakes: Equip with O-ring gaskets designed to make motors weatherproof. Equip motors with internal heaters to permit normal operation at minus 40 degreesF.
   5. Nonspring-Return Motors: For dampers larger than 25 sq. ft., size motor for running torque rating of 150 in. x lbf and breakaway torque rating of 300 in. x lbf.
   6. Electrical Connection: 115 V, single phase, 60 Hz.

2.08 TURNING VANES

A. Fabricate to comply with SMACNA’s “HVAC Duct Construction Standards--Metal and Flexible” for vanes and vane runners. Vane runners shall automatically align vanes.

B. Manufactured Turning Vanes: Fabricate 1-1/2-inch-wide, double-vane, curved blades of galvanized sheet steel set 3/4 inch o.c.; support with bars perpendicular to blades set 2 inches o.c.; and set into vane runners suitable for duct mounting.
   1. Available Manufacturers:
      a. Ductmate Industries, Inc.
      b. Duro Dyne Corp.
      c. METALAIRE, Inc.
      d. Ward Industries, Inc.
C. Acoustic Turning Vanes: Fabricate airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

2.09 DUCT-MOUNTING ACCESS DOORS

A. General Description: Fabricate doors airtight and suitable for duct pressure class.

B. Door: Double wall, duct mounting, and rectangular; fabricated of galvanized sheet metal with insulation fill and thickness as indicated for duct pressure class. Include vision panel where indicated. Include 1-by-1-inch butt or piano hinge and cam latches.

1. Available Manufacturers:
   a. American Warming and Ventilating.
   b. CESCO Products.
   c. Ductmate Industries, Inc.
   d. Flexmaster U.S.A., Inc.
   e. Greenheck.
   g. Nailor Industries Inc.
   h. Ventfabrics, Inc.
   i. Ward Industries, Inc.

2. Frame: Galvanized sheet steel, with bend-over tabs and foam gaskets.

3. Provide number of hinges and locks as follows:
   a. Less Than 12 Inches Square: Secure with two sash locks.
   b. Up to 18 Inches Square: Two hinges and two sash locks.
   c. Up to 24 by 48 Inches: Three hinges and two compression latches.
   d. Sizes 24 by 48 Inches and Larger: One additional hinge.

C. Door: Double wall, duct mounting, and round; fabricated of galvanized sheet metal with insulation fill and 1-inch thickness. Include cam latches.

1. Available Manufacturers:
   a. Ductmate Industries, Inc.
   b. Flexmaster U.S.A., Inc.

2. Frame: Galvanized sheet steel, with spin-in notched frame.

D. Seal around frame attachment to duct and door to frame with neoprene or foam rubber.

E. Insulation: 1-inch-thick, fibrous-glass or polystyrene-foam board.
2.10 FLEXIBLE CONNECTORS

A. Available Manufacturers:
   1. Ductmate Industries, Inc.
   2. Duro Dyne Corp.
   3. Ventfabrics, Inc.

B. General Description: Flame-retardant or noncombustible fabrics, coatings, and adhesives complying with UL 181, Class 1.

   1. Minimum Weight: 26 oz./sq. yd.
   2. Tensile Strength: 480 lbf/inch in the warp and 360 lbf/inch in the filling.
   3. Service Temperature: Minus 40 to plus 200 degreesF.

2.11 FLEXIBLE DUCTS

A. Available Manufacturers:
   1. Flexmaster U.S.A., Inc.
   2. Hart & Cooley, Inc.

B. Noninsulated-Duct Connectors: UL 181, Class 1, multiple layers of aluminum laminate supported by helically wound, spring-steel wire.
   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 20 to plus 210 degreesF.

C. Insulated-Duct Connectors: UL 181, Class 1, 2-ply vinyl film supported by helically wound, spring-steel wire; fibrous-glass insulation; polyethylene vapor barrier film.
   1. Pressure Rating: 10-inch wg positive and 1.0-inch wg negative.
   3. Temperature Range: Minus 10 to plus 160 degreesF.

D. Flexible Duct Clamps: Stainless-steel band with cadmium-plated hex screw to tighten band with a worm-gear action, in sizes 3 through 18 inches to suit duct size.

2.12 DUCT ACCESSORY HARDWARE

A. Instrument Test Holes: Cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments and of length to suit duct insulation thickness.
B. Adhesives: High strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

PART 3 - EXECUTION

3.01 APPLICATION AND INSTALLATION

A. Install duct accessories according to applicable details in SMACNA's "HVAC Duct Construction Standards--Metal and Flexible" for metal ducts and in NAIMA AH116, "Fibrous Glass Duct Construction Standards," for fibrous-glass ducts.

B. Provide duct accessories of materials suited to duct materials; use galvanized-steel accessories in galvanized-steel and fibrous-glass ducts, stainless-steel accessories in stainless-steel ducts, and aluminum accessories in aluminum ducts.

C. Install backdraft dampers on exhaust fans or exhaust ducts nearest to outside and where indicated.

D. Install volume dampers in ducts with liner; avoid damage to and erosion of duct liner.

E. Provide balancing dampers at points on supply, return, and exhaust systems where branches lead from larger ducts as required for air balancing. Install at a minimum of two duct widths from branch takeoff.

F. Provide test holes at fan inlets and outlets and elsewhere as indicated.

G. Install fire and smoke dampers, with fusible links, according to manufacturer’s UL-approved written instructions.

H. Install duct access doors to allow for inspecting, adjusting, and maintaining accessories and terminal units as follows:

1. On both sides of duct coils.
2. Downstream from volume dampers, turning vanes, and equipment.
3. Adjacent to fire or smoke dampers, providing access to reset or reinstall fusible links.
4. To interior of ducts for cleaning; before and after each change in direction, at maximum 50-foot spacing.
5. On sides of ducts where adequate clearance is available.

I. Install the following sizes for duct-mounting, rectangular access doors:

1. One-Hand or Inspection Access: 8 by 5 inches.
2. Two-Hand Access: 12 by 6 inches.
J. Install the following sizes for duct-mounting, round access doors:
   1. One-Hand or Inspection Access: 8 inches in diameter.
   3. Head and Hand Access: 12 inches in diameter.

K. Label access doors according to Section 23 05 53, Identification for HVAC Piping and Equipment.

L. Install flexible connectors immediately adjacent to equipment in ducts associated with fans and motorized equipment supported by vibration isolators.

M. For fans developing static pressures of 5-inch wg and higher, cover flexible connectors with loaded vinyl sheet held in place with metal straps.

N. Connect terminal units to supply ducts directly or with maximum 12-inch lengths of flexible duct. Do not use flexible ducts to change directions.

O. Connect diffusers or light troffer boots to low pressure ducts directly or with maximum 60-inch lengths of flexible duct clamped or strapped in place.

P. Connect flexible ducts to metal ducts with draw bands.

Q. Install duct test holes where indicated and required for testing and balancing purposes.

3.02 ADJUSTING

A. Adjust duct accessories for proper settings.

B. Adjust fire and smoke dampers for proper action.

C. Final positioning of manual-volume dampers is specified in Section 23 05 93, Testing, Adjusting, and Balancing for HVAC.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes the specifications for the following:
   1. Centrifugal roof ventilators.
   2. Centrifugal wall ventilators.
   3. Ceiling-mounting ventilators.
   4. In-line centrifugal fans.

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 07 72 00, Roof Accessories.
   3. Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.
   4. Section 23 33 00, Air Duct Accessories.
   5. Section 26 05 25, Wire and Cable.
   6. Section 26 05 26, Grounding and Bonding Electrical Systems.

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. National Fire Protection Association
      a. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."

1.03 SUBMITTALS

A. Product Data: Include rated capacities, furnished specialties, and accessories for each type of product indicated and include the following:

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

C. Field quality-control test reports.

D. Operation and maintenance data.
1.04 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory to authorities having jurisdiction, and marked for intended use.

B. NEMA Compliance: Motors and electrical accessories shall comply with NEMA standards.

C. UL Standard: Power ventilators shall comply with UL 705.

PART 2 - PRODUCTS

2.01 CENTRIFUGAL ROOF VENTILATORS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

B. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or a comparable product by one of the following:

2. Aerovent; a Twin City Fan Company.
3. American Coolair Corp.
4. Ammerman; General Resource Corp.
5. Breidert Air Products.
7. Carnes Company HVAC.
8. Central Blower Co.
10. Delhi Industries Inc.
12. Hartzell Fan, Inc.
13. JencoFan; Div. of Breidert Air Products.
14. Loren Cook Company.
15. NuTone Inc.
17. Quietaire Corporation.

C. Description: Direct- or belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, curb base, and accessories.
D. Housing: Removable, spun-aluminum, dome top and outlet baffle; square, one-piece, aluminum base with venturi inlet cone.
   1. Hinged Subbase: Galvanized-steel hinged arrangement permitting service and maintenance.

E. Fan Wheels: Aluminum hub and wheel with backward-inclined blades.

F. Belt-Driven Drive Assembly: Resiliently mounted to housing, with the following features:
   1. Fan Shaft: Turned, ground, and polished steel; keyed to wheel hub.
   4. Fan and motor isolated from exhaust airstream.

G. Accessories:
   1. Bird Screens: Removable, 1/2-inch mesh, aluminum or brass wire.
   2. Dampers: Counterbalanced, parallel-blade, backdraft dampers mounted in curb base; factory set to close when fan stops.
   3. Motorized Dampers: Parallel-blade dampers mounted in curb base with electric actuator; wired to close when fan stops.
   4. Motor Starter: Magnetic full-voltage type with heavy-duty relay contacts, and in accordance with the requirements of Section 26 29 13, Enclosed Controllers.

H. Roof Curbs: Galvanized steel; mitered and welded corners; 1-1/2-inch thick, rigid, fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to suit roof opening and fan base.
   2. Overall Height: 12 inches 18 inches.
   5. Metal Liner: Galvanized steel.
   7. Mounting Pedestal: Galvanized steel with removable access panel.
   8. Vented Curb: Unlined with louvered vents in vertical sides.

2.02 CEILING-MOUNTING VENTILATORS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
B. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or a comparable product by one of the following:

1. American Coolair Corp.
2. Ammerman; General Resource Corp.
3. Breidert Air Products.
5. Carnes Company HVAC.
7. FloAire.
8. Greenheck.
9. JencoFan; Div. of Breidert Air Products.
10. Loren Cook Company.
11. NuTone Inc.
12. Penn Ventilation.

C. Description: Centrifugal fans designed for installing in ceiling or wall or for concealed in-line applications.

D. Housing: Steel, lined with acoustical insulation.

E. Fan Wheel: Centrifugal wheels directly mounted on motor shaft. Fan shrouds, motor, and fan wheel shall be removable for service.

F. Grille: Stainless steel, louvered grille with flange on intake and thumbscrew attachment to fan housing.

G. Electrical Requirements: Junction box for electrical connection on housing and receptacle for motor plug-in.

H. Accessories:

1. Motor Starter: Magnetic full-voltage type with heavy-duty relay contacts, and in accordance with the requirements of Section 26 29 13, Enclosed Controllers.
2. Filter: Washable aluminum to fit between fan and grille.
4. Manufacturer's standard roof jack or wall cap, and transition fittings.

2.03 IN-LINE CENTRIFUGAL FANS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:
B. Basis-of-Design Product: Subject to compliance with requirements, provide the product indicated on Drawings or a comparable product by one of the following:

2. American Coolair Corp.
3. Ammerman; General Resource Corp.
4. Bayley Fans; a division of Lau Industries, Inc.
5. Breidert Air Products.
6. Carnes Company HVAC.
7. FloAire.
8. Greenheck.
9. Hartzell Fan, Inc.
10. JencoFan; Div. of Breidert Air Products.
11. Loren Cook Company.
13. Penn Ventilation.

C. Description: In-line, belt-driven centrifugal fans consisting of housing, wheel, outlet guide vanes, fan shaft, bearings, motor, drive assembly, mounting brackets, and accessories.

D. Housing: Split, spun aluminum with aluminum straightening vanes, inlet and outlet flanges, and support bracket adaptable to floor, side wall, or ceiling mounting.

E. Direct-Driven Units: Motor mounted in airstream, factory wired to disconnect switch located on outside of fan housing; with wheel, inlet cone, and motor on swing-out service door.

F. Belt-Driven Units: Motor mounted on adjustable base, with adjustable sheaves, enclosure around belts within fan housing, and lubricating tubes from fan bearings extended to outside of fan housing.

G. Fan Wheels: Aluminum, airfoil blades welded to aluminum hub.

H. Accessories:

1. Motor Starter: Magnetic full-voltage type with heavy-duty relay contacts, and in accordance with the requirements of Section 26 29 13, Enclosed Controllers.
2. Volume-Control Damper: Manually operated with quadrant lock, located in fan outlet.
3. Companion Flanges: For inlet and outlet duct connections.
4. Fan Guards: 1/2- by 1-inch mesh of galvanized steel in removable frame. Provide guard for inlet or outlet for units not connected to ductwork.
5. Motor and Drive Cover (Belt Guard): Epoxy-coated steel.

2.04 MOTORS

A. Comply with requirements in Section 23 05 13 Common Motor Requirements for HVAC Equipment.

B. Enclosure Type: Totally enclosed, fan cooled.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install power ventilators level and plumb.

B. Support units using restrained spring isolators having a static deflection of 1 inch. Vibration- and seismic-control devices are specified in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.

C. Secure vibration and seismic controls to concrete bases using anchor bolts cast in concrete base.

D. Install floor-mounting units on concrete bases. Concrete, reinforcement, and formwork requirements are specified in Section 03 30 00, Cast-in-Place Concrete.

E. Secure roof-mounting fans to roof curbs with cadmium-plated hardware. Refer to Section 07 72 00, Roof Accessories, for installation of roof curbs.

F. Ceiling Units: Suspend units from structure; use steel wire or metal straps.

G. Support suspended units from structure using threaded steel rods and spring hangers with vertical-limit stops having a static deflection of 1 inch. Vibration-control devices are specified in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.

H. Install units with clearances for service and maintenance.

I. Label units according to requirements specified in Section 23 05 53, Identification for HVAC Piping and Equipment.

J. Duct installation and connection requirements are specified in other Division 23, Heating, Ventilation, and Air Conditioning (HVAC), Sections. Contract Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connectors. Flexible connectors are specified in Section 23 33 00, Air Duct Accessories.

K. Install ducts adjacent to power ventilators to allow service and maintenance.

L. Ground equipment according to Section 26 05 26, Grounding and Bonding Electrical Systems.

M. Connect wiring according to Section 26 05 25, Wire and Cable.

3.02 FIELD QUALITY CONTROL

A. Perform the following field tests and inspections and prepare test reports:

1. Verify that shipping, blocking, and bracing are removed.
2. Verify that unit is secure on mountings and supporting devices and that connections to ducts and electrical components are complete. Verify that proper thermal-overload protection is installed in motors, starters, and disconnect switches.

3. Verify that cleaning and adjusting are complete.

4. Disconnect fan drive from motor, verify proper motor rotation direction, and verify fan wheel free rotation and smooth bearing operation. Reconnect fan drive system, align and adjust belts, and install belt guards.

5. Adjust belt tension.

6. Adjust damper linkages for proper damper operation.

7. Verify lubrication for bearings and other moving parts.

8. Verify that manual and automatic volume control and fire and smoke dampers in connected ductwork systems are in fully open position.

9. Disable automatic temperature-control operators, energize motor and adjust fan to indicated rpm, and measure and record motor voltage and amperage.

10. Shut unit down and reconnect automatic temperature-control operators.

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

B. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

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CONTRACT SPECIFICATIONS

SECTION 23 37 13
DIFFUSERS, REGISTERS, AND GRILLES

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes ceiling- and wall-mounted diffusers, registers, and grilles.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
      a. ASHRAE 70 Method of Testing the Performance of Air Outlets and Air Inlets

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: For each product indicated
C. Data Sheet: Indicate materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
D. Diffuser, Register, and Grille Schedule: Indicate Contract Drawing designation, room location, quantity, model number, size, and accessories furnished.

PART 2 - PRODUCTS

2.01 MANUFACTURERS
A. In other Part 2 articles where titles below introduce lists, the following requirements apply to product selection:
   1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

2.02 GRILLES AND REGISTERS
A. Adjustable Bar Grille:
   1. Available Products: see schedule
   2. Available Manufacturers:
b. Anemostat; a Mestek Company.
c. Carnes.
d. Dayus Register & Grille.
f. Krueger.
g. METALAIRE, Inc.; Metal Industries Inc.
h. Nailor Industries of Texas Inc.
i. Price Industries.
j. Titus.
k. Tuttle & Bailey.


5. Face Blade Arrangement: Fixed horizontal spaced 1/2 inch apart.


7. Mounting: as scheduled.

8. Damper Type: Opposed blade with spring-closing and UL-listed fusible link for 160 degrees F.


B. Fixed Face Grille:

1. Available Manufacturers:

b. Anemostat; a Mestek Company.
c. Carnes.
d. Dayus Register & Grille.
f. Krueger.
g. Nailor Industries of Texas Inc.
h. Price Industries.
i. Titus.
j. Tuttle & Bailey.

7. Damper Type: Opposed blade with spring-closing and UL-listed fusible link for 160 degrees F.

2.03 CEILING DIFFUSER OUTLETS

A. Round Ceiling Diffuser:
1. Available Manufacturers:
   a. Anemostat; a Mestek Company.
   b. Carnes.
   d. METALAIRE, Inc.; Metal Industries Inc.
   e. Nailor Industries of Texas Inc.
   f. Price Industries.
   g. Titus.
   h. Tuttle & Bailey.
4. Face Style: Four cone.
6. Dampers: Combination damper and grid.
7. Accessories:
   a. Equaling grid.
   b. Plaster ring.
   c. Safety chain.
   d. Wire guard.
   e. Sectorizing baffles.
   f. Operating rod extension.

B. Rectangular and Square Ceiling Diffusers:
1. Available Manufacturers:
   b. Anemostat; a Mestek Company.
   c. Carnes.
   e. Krueger.
   f. METALAIRE, Inc.; Metal Industries Inc.
   g. Nailor Industries of Texas Inc.
   h. Price Industries.
   i. Titus.
   j. Tuttle & Bailey.


4. Face Size: 24 by 24 inches.

5. Face Style: Four cone.

6. Mounting: As scheduled


9. Accessories:
   a. Equaling grid.
   b. Plaster ring.
   c. Safety chain.
   d. Wire guard.
   e. Sectorizing baffles.
   f. Operating rod extension.

2.04 SOURCE QUALITY CONTROL

A. Verification of Performance: Rate diffusers, registers, and grilles according to ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."
PART 3 - EXECUTION

3.01 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.

B. Ceiling-Mounted Outlets and Inlets: Contract Drawings indicate general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been indicated to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations where indicated, as much as practicable. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify Resident Engineer for a determination of final location.

C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.02 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to air patterns indicated, or as directed, before starting air balancing.

END OF SECTION
SECTION 23 37 23
HVAC GRAVITY VENTILATORS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the following types of roof-mounting intake and relief ventilators:

1. Roof hoods.

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 07 72 00, Roof Accessories.
2. Section 07 92 00, Joint Sealants.
3. Section 23 05 53, Identification for HVAC Piping and Equipment.
4. Section 23 31 13, Metal Ducts.

1.02 REFERENCES

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

1. American Society for Testing and Materials International (ASTM)
   a. ASTM B221 Aluminum and Aluminum Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
   b. ASTM B209 Aluminum and Aluminum Alloy Sheet and Plate
   c. ASTM A653 Steel Sheet, Zinc-coated (Galvanized) or Zinc-Iron Alloy Coated (Galvannealed) by the Hot-Dip Process
   d. ASTM A666 Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
   e. ASTM E488 Standard Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel
   f. ASTM D1187 Asphalt-Base Emulsions for Use as Protective Coatings for Metal
   g. ASTM A780 Standard Specification for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

2. American Welding Society (AWS)
   a. AWS D1.2 Structural Welding Code – Aluminum
b. AWS D1.3 Structural Welding Code – Sheet Steel

3. Sheet Metal and Air Conditioning Contractors’ National Association (SMACNA)
   a. SMACNA HVAC duct construction standards – metal and flexible

1.03 PERFORMANCE REQUIREMENTS

A. Structural Performance: Intake and relief ventilators shall be capable of withstanding the effects of gravity loads, wind loads, seismic loads, and thermal movements without permanent deformation of components, noise or metal fatigue, or permanent damage to fasteners and anchors.

1.04 SUBMITTALS

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

B. Product Data: For each type of product indicated. For louveres specified to bear AMCA seal, include printed catalog pages showing specified models with appropriate AMCA Certified Ratings Seals.

C. Shop Drawings: For intake and relief ventilators. Include plans, elevations, sections, details, and ventilator attachments to curbs and curb attachments to roof structure.

D. Coordination Drawings: Roof framing plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, based on input from installers of the items involved:
   1. Structural members to which roof curbs and ventilators will be attached.
   2. Sizes and locations of roof openings.

E. Samples for Verification: For each type of exposed finish required for intake and relief ventilators.

F. Welding certificates.

1.05 QUALITY ASSURANCE

A. Source Limitations: Obtain ventilators through one source from a single manufacturer where indicated to be of same type, design, or factory-applied color finish.

B. Product Options: Information on Contract Drawings and in Contract Specifications establishes requirements for system’s aesthetic effects and performance characteristics. Aesthetic effects are indicated by dimensions, arrangements, alignment, and profiles of components and assemblies as they relate to sightlines, to one another, and to adjoining construction. Performance characteristics are indicated by criteria subject to verification by one or more methods including preconstruction testing, field testing, and in-service performance.

C. Product Options: Contract Drawings indicate size, profiles, and dimensional requirements of intake and relief ventilators and are based on the specific equipment indicated. Refer Section 01 60 00, Product Requirements.
   1. Do not modify intended aesthetic effects, as judged solely by Resident Engineer, except with Resident Engineer's approval. If modifications are proposed, submit comprehensive explanatory data to Resident Engineer for review.
D. Welding: Qualify procedures and personnel according to the following:


2. AWS D1.3, "Structural Welding Code--Sheet Steel."

1.06 COORDINATION

A. Coordinate installation of roof curbs and roof penetrations. These items are specified in Section 07 72 00, Roof Accessories.

PART 1 - PRODUCTS

1.07 MANUFACTURERS

A. In other Part 2 Articles where titles below introduce lists, the following requirements apply to product selection:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, manufacturers specified.

1.08 MATERIALS

A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5 or T-52.

B. Aluminum Sheet: ASTM B 209, Alloy 3003 or 5005 with temper as required for forming or as otherwise recommended by metal producer for required finish.

C. Galvanized-Steel Sheet: ASTM A 653, G90 zinc coating, mill phosphatized.

D. Stainless-Steel Sheet: ASTM A 666, Type 304, with No. 4 finish.

E. Fasteners: Same basic metal and alloy as fastened metal or 300 Series stainless steel, unless otherwise indicated. Do not use metals that are incompatible with joined materials.

1. Use types and sizes to suit unit installation conditions.

2. Use Phillips flat-head screws for exposed fasteners, unless otherwise indicated.

F. Post-Installed Fasteners for Concrete and Masonry: Torque-controlled expansion anchors, made from stainless-steel components, with capability to sustain, without failure, a load equal to four times the loads imposed, for concrete, or six times the load imposed, for masonry, as determined by testing per ASTM E 488, conducted by a qualified independent testing agency.

G. Bituminous Paint: Cold-applied asphalt emulsion complying with ASTM D 1187.

1.09 FABRICATION, GENERAL

A. Factory or shop fabricate intake and relief ventilators to minimize field splicing and assembly. Disassemble units to the minimum extent as necessary for shipping and handling. Clearly mark units for reassembly and coordinated installation.
B. Fabricate frames, including integral bases, to fit in openings of sizes indicated, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.

C. Fabricate units with closely fitted joints and exposed connections accurately located and secured.

D. Fabricate supports, anchorages, and accessories required for complete assembly.

E. Perform shop welding by AWS-certified procedures and personnel.

1.10 ROOF HOODS

A. Available Manufacturers:
   2. Aerovent; a Twin City Fan company.
   3. Carnes.
   5. JencoFan.
   7. Penn Ventilation.

B. Factory or shop fabricate according to SMACNA's "HVAC Duct Construction Standards - Metal and Flexible," Figures 5-6 and 5-7.

C. Materials: Aluminum sheet, minimum 0.063-inch-thick base and 0.050-inch-thick hood; suitably reinforced.

D. Roof Curbs: Galvanized-steel sheet; with mitered and welded corners; 1-1/2-inch-thick, rigid fiberglass insulation adhered to inside walls; and 1-1/2-inch wood nailer. Size as required to fit roof opening and ventilator base.
   1. Configuration: Self-flashing without a cant strip, with mounting flange.
   2. Overall Height: 12 inches.

E. Bird Screening: Aluminum, 1/2-inch-square mesh, 0.063-inch wire.

F. Insect Screening: Aluminum, 18-by-16 mesh, 0.012-inch wire.

G. Galvanized-Steel Sheet Finish:
   1. Surface Preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas and repair galvanizing according to ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
   2. Factory Priming for Field-Painted Finish: Where field painting after installation is indicated, apply an air-dried primer immediately after cleaning and pretreating.
   3. Baked-Enamel Finish: Immediately after cleaning and pretreating, apply manufacturer's standard finish consisting of prime coat and thermosetting
topcoat, with a minimum dry film thickness of 1 mil for topcoat and an overall minimum dry film thickness of 2 mils.

a. Color and Gloss: As indicated by manufacturer's designations.

PART 2 - EXECUTION

1.11 INSTALLATION

A. Install intake and relief ventilators level, plumb, and at indicated alignment with adjacent work.

B. Secure intake and relief ventilators to roof curbs with cadmium-plated hardware. Use concealed anchorages where possible. Refer to Section 07 72 00, Roof Accessories, for installation of roof curbs.

C. Install intake and relief ventilators with clearances for service and maintenance.

D. Install perimeter reveals and openings of uniform width for sealants and joint fillers, as indicated.

E. Install concealed gaskets, flashings, joint fillers, and insulation as installation progresses. Comply with Section, 07 92 00, Joint Sealants, for sealants applied during installation.

F. Label intake and relief ventilators according to requirements specified in Section 23 05 53, Identification for HVAC Piping and Equipment.

G. Protect galvanized and nonferrous-metal surfaces from corrosion or galvanic action by applying a heavy coating of bituminous paint on surfaces that will be in contact with concrete, masonry, or dissimilar metals.

H. Repair finishes damaged by cutting, welding, soldering, and grinding. Restore finishes so no evidence remains of corrective work. Return items that cannot be refinished in the field to the factory, make required alterations, and refinish entire unit or provide new units.

1.12 CONNECTIONS

A. Duct installation and connection requirements are specified in Section 23 31 13, Metal Ducts. Contract Drawings indicate general arrangement of ducts and duct accessories.

1.13 ADJUSTING

A. Adjust damper linkages for proper damper operation.

END OF SECTION
SECTION 23 41 00
PARTICULATE AIR FILTRATION

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for factory-fabricated air-filter devices and media used to remove particulate matter from air for HVAC applications.

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

1. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electric Code
   b. NFPA 90A Installation of Air Conditioning and Ventilating Systems
   c. NFPA 90B Installation of Warm Air Heating and Air-Conditioning Systems

2. The Air-Conditioning and Refrigeration Institute (ARI)
   a. ARI 850 Commercial and Industrial Air Filter Equipment

3. American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
   a. ASHRAE 52.1 Gravimetric and Dust-Spot Procedures for Testing Air-Cleaning Devices Used in General Ventilation for Removing Particulate Matter
   b. ASHRAE 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

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

B. Product Data: Include dimensions; required clearances and access; rated flow capacity, including initial and final pressure drop at rated airflow; efficiency and test method; fire classification; furnished specialties; and accessories for each unit indicated.

C. Shop Drawings: Include plans, elevations, sections, and details to illustrate component assemblies and attachments.

1. Show filter rack assembly, dimensions, materials, and methods of assembly of components.

2. Include setting drawings, templates, and requirements for installing anchor bolts and anchorages.
D. Operation and maintenance data.

1.04 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable to authorities having jurisdiction, and marked for intended use.

B. Comply with ARI 850.

C. Comply with ASHRAE 52.1 and ASHRAE 52.2 for method of testing and rating air-filter units.

D. Comply with NFPA 90A and NFPA 90B.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. AAF International.
3. Airguard Industries, Inc.
4. Barnebey & Sutcliffe Corp.
5. Columbus Industries, Inc.
6. CRS Industries, Inc.; CosaTron Div.
7. D Mark Inc.
8. Farr Co.
10. Flanders/CSC Corp.
11. Flanders Filters, Inc.
12. General Filters Inc.
15. LakeAir International, Inc.
17. Purafil, Inc.
18. Research Products Corp.
B. Disposable Panel Filters: Factory-fabricated, viscous-coated, flat-panel-type, disposable air filters with holding frames.
   1. Media: Interlaced glass fibers sprayed with nonflammable adhesive.
   2. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.
   3. Duct-Mounting Frames: Welded, galvanized steel with gaskets and fasteners and suitable for bolting together into built-up filter banks.

C. Extended-Surface, Disposable Panel Filters: Factory-fabricated, dry, extended-surface filters with holding frames.
   1. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
   3. Duct-Mounting Frames: Welded, galvanized steel with gaskets and fasteners, and suitable for bolting together into built-up filter banks.

D. Side-Service Housings: Factory-assembled, side-service housings, constructed of galvanized steel, with flanges to connect to duct system.
   1. Integral Tracks: Accommodate 2-inch disposable or washable filters.
   2. Access Doors: Continuous gaskets on perimeter and positive-locking devices. Arrange so filter cartridges can be loaded from either access door.
   3. Sealing: Incorporate positive-sealing gasket material on channels to seal top and bottom of filter cartridge frames to prevent bypass of unfiltered air.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Position each filter unit with clearance for normal service and maintenance. Anchor filter holding frames to substrate.

B. Install filters in position to prevent passage of unfiltered air.

C. Coordinate filter installations with duct and air-handling unit installations.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for constant-volume, modular air-handling units with
   coils for indoor installations.

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 23 05 00, Common Work Results for HVAC
2. Section 23 05 13, Common Motors Requirements for HVAC Equipment.
3. Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and
   Equipment.
4. Section 23 05 93, Testing, Adjusting, and Balancing for HVAC
5. Section 23 09 00, Instrumentation and Control for HVAC.
6. Section 25 60 00, Building Management System
7. Section 26 05 26, Grounding and Bonding for Electrical Systems.
8. Section 26 29 13, Enclosed Controllers

1.02 REFERENCES

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

1. American Society for Testing and Materials International (ASTM)
   a. ASTM C 1071 Fibrous Glass Duct Lining Insulation (Thermal and Sound
      Absorbing Matter)
   b. ASTM C 411 Standard Test Method for Hot-Surface Performance of
      High-Temperature Thermal Insulation
   c. ASTM C 916 Adhesives for Duct Thermal Insulation

2. National Fire Protection Association (NFPA)
   a. NFPA 70 National Electric Code
   b. NFPA 90A Installation of Air Conditioning and Ventilating Systems
   c. NFPA 90B Installation of Warm Air Heating and Air-Conditioning
      Systems
3. Underwriters Laboratory (UL)
   a. UL 1995 Heating and Cooling Equipment
   b. UL 486A Wire Connectors and Soldering Lugs for Use with Copper Conductors
   c. UL 486B Wire Connectors for Use with Aluminum Conductors

4. The Air-Conditioning and Refrigeration Institute (ARI)
   a. ARI 430 Central Station Air Handling Units

5. American Bearing Manufacturers Association (ABMA)
   a. ABMA 9 Load Ratings and Fatigue Life for Ball Bearings
   b. ABMA 11 Load Ratings and Fatigue Life for Roller Bearings

6. Air Movement and Control Association (AMCA)
   a. AMCA 99-2408 Operating Limits for Centrifugal Fans
   b. AMCA 301 Methods for Calculating Fan Sound Ratings from Laboratory Test Data
   c. AMCA 300 Reverberant Room Method for Sound Testing of Fans
   d. AMCA 210 Laboratory Methods of Testing Fans for Rating
   e. AMCA 500 Test Methods for Louvers, Dampers and Shutters

1.03 SUBMITTALS

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

B. Product Data: For each type of modular indoor air-handling unit indicated. Include the following:

C. Certified fan-performance curves with system operating conditions indicated.
   1. Certified fan-sound power ratings.
   2. Certified coil-performance ratings with system operating conditions indicated.
   3. Motor ratings, electrical characteristics, and motor and fan accessories.
   4. Material gages and finishes.
   5. Filters with performance characteristics.
   6. Dampers, including housings, linkages, and operators.

D. Shop Drawings: Signed and sealed by a qualified professional engineer.

E. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
1. Vibration Isolation Base Details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include auxiliary motor slides and rails, and base weights.

2. Wiring Diagrams: Power, signal, and control wiring.

F. Coordination Drawings: Submit with Shop Drawings. Show mechanical-room layout and relationships between components and adjacent structural and mechanical elements. Show support locations, type of support, and weight on each support. Indicate and certify field measurements. Coordination shall include construction sequencing because the units are larger than will fit through the final building passage ways. If the unit is to be assembled on site coordination of sections must be coordinated with the building limitations.

G. Manufacturer Seismic Qualification Certification: Submit certification that modular indoor air-handling units, accessories, and components will withstand seismic forces defined in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment. Include the following:

H. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

   a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."

I. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

   1. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

J. Field Quality-Control Test Reports: From manufacturer.

1.04 QUALITY ASSURANCE

A. Source Limitations: Obtain modular indoor air-handling units through one source from a single manufacturer.

B. Product Options: Drawings indicate size, profiles, and dimensional requirements of modular indoor air-handling units and are based on the specific system indicated.

C. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable to authorities having jurisdiction, and marked for intended use.

D. NFPA Compliance: Modular indoor air-handling units and components shall be designed, fabricated, and installed in compliance with NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."

E. ARI Certification: Modular indoor air-handling units and their components shall be factory tested according to ARI 430, "Central-Station Air-Handling Units," and shall be listed and labeled by ARI.

F. Comply with NFPA 70.
1.05 COORDINATION

A. Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements are specified in Division 03, Concrete.

B. Coordinate size and location of structural-steel support members.

1.06 EXTRA MATERIALS

A. Furnish extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.

B. Filters: One set for each modular indoor air-handling unit.
   1. Fan Belts: One set for each modular indoor air-handling unit fan.
   2. Gaskets: One set for each access door.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Airtherm Manufacturing Company.
   1. Buffalo Air Handling.
   2. Carrier; Div. of United Technologies Corp.
   3. CES Group Inc.; Governair, Mammoth, Temtrol, Venmar Ventrol, Webco Divisions.
   4. Dunham-Bush, Inc.
   5. Engineered Air.
   7. Trane Company (The); Worldwide Applied Systems Group.

2.02 MANUFACTURED UNITS

A. Modular indoor air-handling units shall be factory assembled complete or in sections and consist of fans, motor and drive assembly, coils, damper, plenums, filters, mixing dampers, control devices, and accessories.

B. Field assembled sections shall be provided with permanent, factory-applied bulb-type gaskets.

C. Air handling unit fans housings shall fit through a standard 36-inch door.
2.03 CABINET

A. Materials: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. Outside Casing: Galvanized steel, 0.0635 inch thick.
   1. Inside Casing: Galvanized steel, 0.0276 inch thick.
   2. Floor Plate: Galvanized steel, 0.1382 inch thick.

C. Cabinet Insulation: Comply with NFPA 90A or NFPA 90B.

D. Materials: ASTM C 1071 with coated surface exposed to airstream to prevent erosion of glass fibers.
   1. Thickness: 2 inches.
   2. Thermal Conductivity (k-Value): 0.26 at 75 deg F mean temperature.
   3. Fire-Hazard Classification: Maximum flame-spread index of 25 and smoke-developed index of 50, when tested according to ASTM C 411.
   4. Liner Adhesive: Comply with NFPA 90A or NFPA 90B and ASTM C 916.
   5. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
   6. Location and Application: Factory applied with adhesive and mechanical fasteners to the internal surface of section panels downstream from and including the cooling coil section.

E. Access Panels and Doors: Same materials and finishes as cabinet, complete with hinges, latches, handles, and gaskets. Inspection and access panels and doors shall be sized and located to allow periodic maintenance and inspections. Provide access panels and doors in the following locations:

F. Fan Section: Doors.
   1. Access Section: Doors.
   2. Damper Section: Doors.
   3. Filter Section: Doors to allow periodic removal and installation of filters.

2.04 FAN SECTION

A. Fan-Section Construction: Belt-driven centrifugal fans consisting of housing, wheel, fan shaft, bearings, motor, drive assembly, and support structure and equipped with formed-steel channel base for integral mounting of fan, motor, and casing panels. Mount fan with vibration isolation.

B. Centrifugal Fan Housings: Formed- and reinforced-steel panels to make curved scroll housings with shaped cutoff, spun-metal inlet bell, and access doors or panels to allow entry to internal parts and components.
C. Panel Bracing: Steel angle- or channel-iron member supports for mounting and supporting fan scroll, wheel, motor, and accessories.
   1. Performance Class: AMCA 99-2408, Class I, II, or III according to scheduled static pressure.
   2. Horizontal Flanged Split Housing: Bolted construction.

D. Fan Assemblies: Statically and dynamically balanced and designed for continuous operation at maximum rated fan speed and motor horsepower.

E. Fan type shall be as scheduled:
   1. Forward-Curved Fan Wheels: Black-enamel or galvanized-steel construction with inlet flange, backplate, and shallow blades with inlet and tip curved forward in direction of airflow and mechanically secured to flange and backplate; cast-steel hub swaged to backplate and fastened to shaft with set screws.
   2. Airfoil-Fan Wheels: Steel construction with smooth curved inlet flange, heavy backplate, and hollow die-formed airfoil-shaped blades continuously welded at tip flange and backplate; cast-iron or cast-steel hub riveted to backplate and fastened to shaft with set screws.

F. Coatings: Powder-baked enamel.

G. Shafts: Statically and dynamically balanced and designed for continuous operation at maximum rated fan speed and motor horsepower, with final alignment and belt adjustment made after installation.

H. Turned, ground, and polished hot-rolled steel with keyway. Ship with a protective coating of lubricating oil.
   1. Designed to operate at no more than 70 percent of first critical speed at top of fan's speed range.

I. Bearings shall be as appropriate for the fan selected.
   1. Ball-Bearing Rating Life: ABMA 9, L₁₀ of 120,000 hours.
   3. Roller-Bearing Rating Life: ABMA 11, L₁₀ of 120,000 hours.

J. Belt Drives: Factory mounted, with final alignment and belt adjustment made after installation and with 1.5 service factor based on fan motor.

K. Pulleys: Cast iron or cast steel with split, tapered bushing; dynamically balanced at factory.
   1. Motor Pulleys: Adjustable pitch for use with 5-hp motors and smaller; fixed pitch for use with motors larger than 5 hp. Select pulley so pitch adjustment is at the middle of adjustment range at fan design conditions.
2. Belts: Oil resistant, nonsparking, and nonstatic; matched for multiple belt drives.

3. Belt Guards: Fabricate to OSHA/SMACNA requirements; 0.1046-inch- thick, 3/4-inch diamond-mesh wire screen welded to steel angle frame or equivalent; prime coated.


L. Vibration Control: Install fans on open-spring vibration isolators having a minimum of 1-inch static deflection and side snubbers.

M. Fan-Section Source Quality Control:

N. Sound Power Level Ratings: Comply with AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans according to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.

1. Factory test fan performance for flow rate, pressure, power, air density, rotation speed, and efficiency. Establish ratings according to AMCA 210, "Laboratory Methods of Testing Fans for Rating."

2.05 MOTORS

A. General: Comply with requirements in Section 23 05 13, Common Motors Requirements for HVAC Equipment.

B. Noise Rating: Quiet.

2.06 STARTERS

A. Starters: As specified in section 26 29 13, Enclosed Controllers.

2.07 COILS

A. Coil Sections: Common or individual, insulated, galvanized-steel casings for heating coils. Design and construct to facilitate removal and replacement of coil for maintenance and to ensure full airflow through coils.


C. Casing Assembly: Flanged type with galvanized-steel frame.

1. Heating Elements: Coiled resistance wire of 80 percent nickel and 20 percent chromium surrounded by compacted magnesium-oxide powder in tubular-steel sheath; with spiral-wound, copper-plated, steel fins continuously brazed to sheath.

2. Overtemperature Protection: Disk-type, automatically resetting, thermal-cutout, safety device; serviceable through terminal box without removing heater from duct or unit.

a. Secondary Protection: Load-carrying, manually resetting or manually replaceable, thermal cutouts; factory wired in series with each heater stage.

D. Control Panel: Remote mounted with disconnecting means and overcurrent protection. Include the following controls:
a. Magnetic contactor.
b. Mercury contactor.
c. Solid-state stepless pulse controller.
d. Toggle switches, one per step.
e. Time-delay relay.
f. Pilot lights, one per step.
g. Airflow proving switch.
h. 15HP motors or larger shall be equipped with soft start controller run command from BMS.

2.08 DAMPERS
A. General: Leakage rate, according to AMCA 500, "Laboratory Methods for Testing Dampers for Rating," shall not exceed 2 percent of air quantity at 2000-fpm face velocity through damper and 4-inch wg pressure differential.
B. Damper Operators: Electric specified in Section 23 09 00, Instrumentation and Control for HVAC.
C. Low-Leakage, Outside-Air Dampers: Double-skin, airfoil-blade galvanized-steel dampers with compressible jamb seals and extruded-vinyl blade edge seals, in parallel-blade arrangement with steel operating rods rotating in stainless-steel sleeve bearings mounted in a single galvanized-steel frame, and with operating rods connected with a common linkage. Leakage rate shall not exceed 5 cfm/sq. ft. at 1-inch wg and 9 cfm/sq. ft. at 4-inch wg.
D. Mixing Boxes: Parallel-blade galvanized-steel dampers mechanically fastened to steel operating rod in reinforced, galvanized-steel cabinet. Connect operating rods with common linkage and interconnect linkages so dampers operate simultaneously.

2.09 CONTROLS
Provide control terminals arranged as shown on Building Management System plans.

2.10 FILTER SECTION
A. Filters: Comply with NFPA 90A.
B. Filter Section: Provide filter holding frames arranged for flat or angular orientation, with access doors on both sides of unit. Filters shall be removable from one side.
C. Disposable Panel Filters: Factory-fabricated, viscous-coated, flat-panel-type, disposable air filters with holding frames.
D. Media: Interlaced glass fibers sprayed with nonflammable adhesive.
   1. Frame: Galvanized steel with metal grid on outlet side, steel rod grid on inlet side, hinged, and with pull and retaining handles.
   2. Duct-Mounting Frames: Welded, galvanized steel with gaskets and fasteners, suitable for bolting together into built-up filter banks.
E. Extended-Surface, Disposable Panel Filters: Factory-fabricated, dry, extended-surface filters with holding frames.

F. Media: Fibrous material formed into deep-V-shaped pleats and held by self-supporting wire grid.
   1. Media and Media-Grid Frame: Galvanized steel.


H. Media: Fibrous material constructed so individual pleats are maintained in tapered form by flexible internal supports under rated-airflow conditions.

**PART 3 - EXECUTION**

3.01 EXAMINATION

A. Examine areas and conditions for compliance with requirements for installation tolerances and other conditions affecting performance.

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

3.02 INSTALLATION

A. Concrete Bases: Install floor mounting units on 4-inch-high concrete bases. See Section 23 05 00, Common Work Results for HVAC, for concrete base materials and fabrication requirements.

B. Install modular indoor air-handling units with the following vibration and seismic-control devices. Vibration and seismic-control devices are specified in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.

C. Units with Internally Isolated Fans: Secure units to anchor bolts installed in concrete bases.

D. Arrange installation of units to provide access space around modular indoor air-handling units for service and maintenance.

3.03 CONNECTIONS

A. Duct installation and connection requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of ducts and duct accessories. Make final duct connections with flexible connections.

B. Electrical: Comply with applicable requirements in Division 26, Electrical, Sections for power wiring, switches, and motor controls.

C. Ground equipment according to Section 26 05 26, Grounding and Bonding for Electrical Systems.
D. Tighten electrical connectors and terminals according to manufacturer's published
 torque-tightening values. If manufacturer's torque values are not indicated, use those
 specified in UL 486A and UL 486B.

3.04 FIELD QUALITY CONTROL

A. Manufacturer's Field Service: Engage a factory-authorized service representative to
 inspect field-assembled components and equipment installation, including piping and
 electrical connections. Report results in writing.

1. Fan Operational Test: After electrical circuitry has been energized, start units to
 confirm proper motor rotation and unit operation. Remove malfunctioning units,
 replace with new units, and retest.

2. Test and adjust controls and safeties. Replace damaged and malfunctioning
 controls and equipment.

3.05 STARTUP SERVICE

A. Engage a factory-authorized service representative to perform startup service.

B. Final Checks before Startup: Perform the following:

C. Verify that shipping, blocking, and bracing are removed.

1. Verify that unit is secure on mountings and supporting devices and that
 connections to piping, ducts, and electrical systems are complete. Verify that
 proper thermal-overload protection is installed in motors, starters, and disconnect
 switches.

2. Perform cleaning and adjusting specified herein.

3. Disconnect fan drive from motor, verify proper motor rotation direction, and verify
 free fan wheel rotation and smooth bearing operations. Reconnect fan drive
 system, align belts, and install belt guards.

4. Lubricate bearings, pulleys, belts, and other moving parts with factory-
 recommended lubricants.

5. Set outside- and return-air mixing dampers to minimum outside-air setting.


7. Install clean filters.

8. Verify that manual and automatic volume control and fire and smoke dampers in
 connected duct systems are in fully open position.

D. Starting procedures for modular indoor air-handling units include the following:

E. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan
 to indicated rpm. Replace fan and motor pulleys as required to achieve design conditions.

1. Measure and record motor electrical values for voltage and amperage.

2. Manually operate dampers from fully closed to fully open position and record fan
 performance.
F. Refer to Section 23 05 93, Testing, Adjusting, and Balancing for HVAC, for modular indoor air-handling system testing, adjusting, and balancing.

3.06 ADJUSTING
A. Adjust damper linkages for proper damper operation.

3.07 CLEANING
A. Clean modular indoor air-handling units internally, on completion of installation, according to manufacturer's written instructions. Clean fan interiors to remove foreign material and construction dirt and dust. Vacuum clean fan wheels, cabinets, and coils entering air face.

B. After completing system installation and testing, adjusting, and balancing modular indoor air-handling and air-distribution systems, clean filter housings and install new filters.

3.08 DEMONSTRATION
A. Engage a factory-authorized service representative to train Sound Transit’s maintenance personnel to adjust, operate, and maintain modular indoor air-handling units.

END OF SECTION
SECTION 23 74 13
PACKAGED OUTDOOR CENTRAL STATION AIR HANDLING UNITS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes packaged, outdoor, central-station air-handling units (rooftop units) with the following components and accessories:

1. Electric-heating coils.
2. Economizer outdoor- and return-air damper section.
3. Integral, space temperature controls.
4. Roof curbs.
5. Motors and starters.
6. Fans
7. Enclosures

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 23 05 00, Common Work Results for HVAC
2. Section 23 05 13, Common Motors Requirements for HVAC Equipment.
3. Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.
4. Section 23 05 93, Testing, Adjusting, and Balancing for HVAC
5. Section 23 09 00, Instrumentation and Control for HVAC.
6. Section 25 60 00, Building Management System
7. Section 26 05 26, Grounding and Bonding for Electrical Systems.
8. Section 26 29 13, Enclosed Controllers

1.02 REFERENCES

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

1. American Society for Testing and Materials International (ASTM)
   a. ASTM C 1071 Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
b. ASTM C 916 Standard Specification for Adhesives for Duct Thermal Insulation

2. National Fire Protection Association (NFPA)
   a. NFPA 90A Installation of Air Conditioning and Ventilating Systems
   b. NFPA 90B Installation of Warm Air Heating and Air-Conditioning Systems
   c. NFPA 70 National Electric Code

3. Underwriters Laboratories (UL)
   a. UL 1995 Heating and Cooling Equipment

4. American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)
   a. ASHRAE 15 Refrigeration System Safety
   b. ASHREA 33 Methods of testing cooling and heating coils
      c. ASHRAE/IESNA 90.1 Minimum efficiency of heating and cooling.
      d. ASHRAE 52.1 Gravimetric and Dust Spot Procedures for Testing Air-Cleaning Devices used in General Ventilation for Removing Particulate Matter
      e. ASHRAE 52.2 Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size

1.03 DEFINITIONS
A. DDC: Direct-digital controls.
B. ECM: Electrically commutated motor.
C. RTU: Rooftop unit. As used in this Section, this abbreviation means packaged, outdoor, central-station air-handling units. This abbreviation is used regardless of whether the unit is mounted on the roof or on a concrete base on ground.
D. Supply-Air Fan: The fan providing supply air to conditioned space. "Supply air" is defined as the air entering a space from air-conditioning, heating, or ventilating apparatus.

1.04 PERFORMANCE REQUIREMENTS
A. Delegated Design: Design RTU supports to comply with wind and seismic performance requirements, including comprehensive engineering analysis by a qualified professional engineer, using performance requirements and design criteria indicated.
B. Wind-Restraint Performance:
   1. Basic Wind Speed: 80 mph.
   2. Building Classification Category: III.
3. Minimum 10 lb/sq. ft multiplied by the maximum area of the mechanical component projected on a vertical plane that is normal to the wind direction, and 45 degrees either side of normal.

C. Seismic Performance: RTUs shall withstand the effects of earthquake motions determined according to SEI/ASCE 7.
   1. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

1.05 SUBMITTALS

A. Product Data: Include manufacturer’s technical data for each RTU, including rated capacities, dimensions, required clearances, characteristics, furnished specialties, and accessories.

B. LEED Submittals:
   1. Product Data for Credit EA 4: For refrigerants, including printed statement that refrigerants are free of HCFCs.
   2. Product Data for Credit EA 5: For continuous metering equipment for outdoor airflow and energy consumption.

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

D. Delegated-Design Submittal: For RTU supports indicated to comply with performance requirements and design criteria, including analysis data signed and sealed by the qualified professional engineer responsible for their preparation.
   1. Design Calculations: Calculate requirements for selecting vibration isolators and seismic restraints and for designing vibration isolation bases.
   2. Detail mounting, securing, and flashing of roof curb to roof structure. Indicate coordinating requirements with roof membrane system.
   3. Wind- and Seismic-Restraint Details: Detail fabrication and attachment of wind and seismic restraints and snubbers. Show anchorage details and indicate quantity, diameter, and depth of penetration of anchors.

E. Manufacturer Wind Loading Qualification Certification: Submit certification that specified equipment will withstand wind forces identified in "Performance Requirements" Article and in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.
   1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculations.
   2. Dimensioned Outline Drawings of Equipment Unit: Identify center of wind force and locate and describe mounting and anchorage provisions.
   3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
F. Manufacturer Seismic Qualification Certification: Submit certification that RTUs, accessories, and components will withstand seismic forces defined in "Performance Requirements" Article and in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

G. Coordination Drawings: Plans and other details, drawn to scale, on which the following items are shown and coordinated with each other, using input from Installers of the items involved:

1. Structural members to which RTUs will be attached.

2. Roof openings

3. Roof curbs and flashing.

H. Field quality-control test reports.

I. Operation and Maintenance Data: For RTUs to include in emergency, operation, and maintenance manuals.

J. Warranty: Special warranty specified herein.

1.06 QUALITY ASSURANCE

A. ARI Compliance:

1. Comply with ARI 210/240 and ARI 340/360 for testing and rating energy efficiencies for RTUs.

2. Comply with ARI 270 for testing and rating sound performance for RTUs.

B. ASHRAE Compliance:

1. Comply with ASHRAE 15 for refrigeration system safety.

2. Comply with ASHRAE 33 for methods of testing cooling and heating coils.

3. Comply with ASHRAE/IESNA 90.1 for minimum efficiency of heating and cooling.

C. NFPA Compliance: Comply with NFPA 90A and NFPA 90B.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable Seattle code authority having jurisdiction, and marked for intended use.
1.07 WARRANTY

A. Special Warranty: Manufacturer's standard form in which manufacturer agrees to replace components of RTUs that fail in materials or workmanship within specified warranty period.

1. Warranty Period for Control Boards: Manufacturer's standard, but not less than three years from date of Substantial Completion.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the following:

1. AAON, Inc.
2. Addison Products Company.
3. Carrier Corporation.
4. Engineered Air.
5. Lennox Industries Inc.
7. Trane; American Standard Companies, Inc.
8. YORK International Corporation.

2.02 CASING

A. General Fabrication Requirements for Casings: Formed and reinforced double-wall insulated panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed.

B. Exterior Casing Material: Galvanized steel with factory-painted finish, with pitched roof panels and knockouts with grommet seals for electrical and piping connections and lifting lugs.

1. Exterior Casing Thickness: 0.0626 inch thick.

C. Inner Casing Fabrication Requirements:

1. Inside Casing: Galvanized steel, 0.034 inch thick, perforated 40 percent free area.

D. Casing Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.

1. Materials: ASTM C 1071, Type I.
2. Thickness: 1 inch.
3. Liner materials shall have air-stream surface coated with an erosion- and temperature-resistant coating or faced with a plain or coated fibrous mat or fabric.

4. Liner Adhesive: Comply with ASTM C 916, Type I.

2.03 FANS

A. Belt-Driven Supply-Air Fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the casing. Aluminum or painted-steel wheels, and galvanized- or painted-steel fan scrolls.

B. Seismic Fabrication Requirements: Fabricate fan section, internal mounting frame and attachment to fans, fan housings, motors, casings, accessories, and other fan section components with reinforcement strong enough to withstand seismic forces defined in Division 23 Section "Vibration and Seismic Controls for HVAC Piping and Equipment" when fan-mounted frame and RTU-mounted frame are anchored to building structure.

C. Fan Motor: Comply with requirements in Section 23 05 13 Common Motor Requirements for HVAC Equipment.

D. Motor Starter: Comply with requirements in Section 26 29 13, Enclosed Controllers.

2.04 COILS

A. Electric-Resistance Heating:

1. Open Heating Elements: Resistance wire of 80 percent nickel and 20 percent chromium, supported and insulated by floating ceramic bushings recessed into casing openings, fastened to supporting brackets, and mounted in galvanized-steel frame. Terminate elements in stainless-steel machine-staked terminals secured with stainless-steel hardware.

2. Overtemperature Protection: Disk-type, automatically reset, thermal-cutout, safety device; serviceable through terminal box.

3. Overcurrent Protection: Manual-reset thermal cutouts, factory wired in each heater stage.

4. Control Panel: Unit mounted with disconnecting means and overcurrent protection. Include the following controls:
   a. Magnetic contactors.
   b. Step Controller: Pilot lights and override toggle switch for each step.
   c. Time-delay relay.
   d. Airflow proving switch.

2.05 AIR FILTRATION

A. Minimum arrestance according to ASHRAE 52.1, and a minimum efficiency reporting value (MERV) according to ASHRAE 52.2.

1. Glass Fiber: Minimum 80 percent arrestance, and MERV 5.
2. Pleated: Minimum 90 percent arrestance, and MERV 7.

2.06 DAMPERS
   A. Outdoor-Air Damper: Linked damper blades, for 0 to 25 percent outdoor air, with
      motorized damper filter.
   B. Outdoor- and Return-Air Mixing Dampers: Parallel- or opposed-blade galvanized-steel
      dampers mechanically fastened to cadmium plated for galvanized-steel operating rod in
      reinforced cabinet. Connect operating rods with common linkage and interconnect
      linkages so dampers operate simultaneously.
      1. Damper Motor: Modulating with adjustable minimum position.
      2. Relief-Air Damper: Gravity actuated with bird screen and hood.

2.07 ELECTRICAL POWER CONNECTION
   A. Provide for single connection of power to unit with control-circuit and damper supply
      transformer with built-in overcurrent protection.

2.08 CONTROLS
   A. Control equipment is specified in Section 230 9 00, Instrumentation and Control for
      HVAC.
   B. Control Sequence of operation specified in Section 23 09 93, Sequence of Operations for
      HVAC Controls.
   C. Basic Unit Controls:
      1. Control-voltage transformer.
   D. DDC Controller:
      1. Controller shall have volatile-memory backup.
      2. Safety Control Operation:
   E. Interface Requirements for HVAC Instrumentation and Control System:
      1. Provide control terminals, arranged as shown on building management plans.

2.09 ACCESSORIES
   A. Electric heater with integral thermostat maintains minimum 50 degrees F temperature in
      gas burner compartment.
   B. Duplex, 115-V, ground-fault-interrupter outlet with 15-A overcurrent protection. Include
      transformer if required.
   C. Coil guards of painted, galvanized-steel wire.

2.10 ROOF CURBS
   A. Roof curbs with vibration isolators and wind or seismic restraints are specified in Section
      23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.
B. Materials: Galvanized steel with corrosion-protection coating, watertight gaskets, and factory-installed wood nailer; complying with NRCA standards.

1. Curb Insulation and Adhesive: Comply with NFPA 90A or NFPA 90B.
   a. Materials: ASTM C 1071, Type I or II.
   b. Thickness: 2 inches.

2. Application: Factory applied with adhesive and mechanical fasteners to the internal surface of curb.
   a. Liner Adhesive: Comply with ASTM C 916, Type I.
   b. Mechanical Fasteners: Galvanized steel, suitable for adhesive attachment, mechanical attachment, or welding attachment to duct without damaging liner when applied as recommended by manufacturer and without causing leakage in cabinet.
   c. Liner materials applied in this location shall have air-stream surface coated with a temperature-resistant coating or faced with a plain or coated fibrous mat or fabric depending on service air velocity.
   d. Liner Adhesive: Comply with ASTM C 916, Type I.

C. Curb Height: 12 inches.

D. Wind and Seismic Restraints: Metal brackets compatible with the curb and casing, painted to match RTU, used to anchor unit to the curb, and designed for loads at Project site. Comply with requirements in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment, for wind-load requirements.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine substrates, areas, and conditions, with Installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of RTUs.

B. Examine roughing-in for RTUs to verify actual locations of piping and duct connections before equipment installation.

C. Examine roofs for suitable conditions where RTUs will be installed.

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

3.02 INSTALLATION

A. Equipment Mounting: Install RTUs on concrete base using restrained spring isolators. Comply with requirements for concrete base specified in Section 03 30 00, Cast-in-Place Concrete.

   1. Minimum Deflection: 1 inch.

B. Roof Curb: Install on roof structure or concrete base, level and secure, according to NRCA's "Low-Slope Membrane Roofing Construction Details Manual," Illustration
"Raised Curb Detail for Rooftop Air Handling Units and Ducts." ARI Guideline B. Install RTUs on curbs and coordinate roof penetrations and flashing with roof construction specified in Section 07 72 00, Roof Accessor ies. Secure RTUs to upper curb rail, and secure curb base to roof framing or concrete base with anchor bolts.

C. Unit Support: Install unit level on structural curbs. Coordinate wall penetrations and flashing with wall construction. Secure RTUs to structural support with anchor bolts.

D. Install wind and seismic restraints according to manufacturer's written instructions. Wind and seismically restrained vibration isolation roof-curb rails are specified in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.

3.03 CONNECTIONS
A. Duct installation requirements are specified in other Division 23 Sections. Drawings indicate the general arrangement of ducts. The following are specific connection requirements:
   1. Install ducts to termination at top of roof curb.
   2. Remove roof decking only as required for passage of ducts. Do not cut out decking under entire roof curb.
   3. Connect supply ducts to RTUs with flexible duct connectors specified in Section 23 33 00, Air Duct Accessories.
   4. Install return-air duct continuously through roof structure.

3.04 FIELD QUALITY CONTROL
A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections. Report results in writing.

B. Tests and Inspections:
   1. After installing RTUs and after electrical circuitry has been energized, test units for compliance with requirements.
   2. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

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

3.05 STARTUP SERVICE
A. Complete installation and startup checks according to manufacturer's written instructions and do the following:
   1. Inspect for visible damage to unit casing.
   2. Inspect internal insulation.
3. Verify that labels are clearly visible.
4. Verify that clearances have been provided for servicing.
5. Verify that controls are connected and operable.
6. Verify that filters are installed.
7. Remove packing from vibration isolators.
8. Verify lubrication on fan and motor bearings.
9. Inspect fan-wheel rotation for movement in correct direction without vibration and binding.
10. Adjust fan belts to proper alignment and tension.
11. Start unit according to manufacturer's written instructions.
   a. Complete startup sheets and attach copy with Contractor's startup report.
12. Inspect and record performance of interlocks and protective devices; verify sequences.
13. Operate unit for an initial period as recommended or required by manufacturer.
15. Measure and record the following minimum and maximum airflows. Plot fan volumes on fan curve.
   a. Supply-air volume.
   b. Return-air volume.
   c. Relief-air volume.
   d. Outdoor-air intake volume.
16. Verify operation of remote panel including pilot-light operation and failure modes. Inspect the following:
   b. Low-temperature safety operation.
   c. Filter high-pressure differential alarm.
   d. Economizer to minimum outdoor-air changeover.
   e. Relief-air fan operation.
   f. Smoke and firestat alarms.
17. After startup and performance testing and prior to Substantial Completion, replace existing filters with new filters.
3.06 CLEANING AND ADJUSTING

A. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to site during other-than-normal occupancy hours for this purpose.

B. After completing system installation and testing, adjusting, and balancing RTU and air-distribution systems, clean filter housings and install new filters.

END OF SECTION
SECTION 23 81 23
COMPUTER ROOM AIR CONDITIONERS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes the following types of computer-room air-conditioning units:
   1. Ceiling-mounting units with remote compressor.

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 23 05 00, Common Work Results for HVAC
   2. Section 23 05 13, Common Motors Requirements for HVAC Equipment.
   3. Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.
   4. Section 23 05 93, Testing, Adjusting, and Balancing for HVAC
   5. Section 23 09 00, Instrumentation and Control for HVAC.
   6. Section 26 05 26, Grounding and Bonding for Electrical Systems.
   7. Section 26 29 13, Enclosed Controllers
   8. Section 25 60 00, Building Management System

1.02 REFERENCES

A. This Section incorporates by reference the latest revisions of the following documents.
   1. American Society of Mechanical Engineers (ASME)
      a. Boiler and Pressure Vessel Code (BPVC), Section VII, "Pressure Vessels," Division 01
   2. National Fire Protection Association (NFPA)
      a. NFPA 70 National Electric Code
   3. Underwriter Laboratory (UL)
      a. UL 486A Wire Connectors and Soldering Lugs for Use with Copper Conductors
   4. American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE)
      a. ASHRAE 15, Safety Code for Mechanical Refrigeration

1.03 SUBMITTALS

A. Product Data: Include rated capacities, operating characteristics, furnished specialties, and accessories.

B. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

C. Manufacturer Seismic Qualification Certification: Submit certification that computer-room air-conditioning units, accessories, and components will withstand seismic forces defined in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment. Include the following:
   1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.
      a. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
   2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.
   3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Field quality-control test reports.

E. Operation and Maintenance Data: For computer-room air-conditioning units to include in emergency, operation, and maintenance manuals.

F. Warranties: Special warranties specified in this Section.

G. LEED Submittals:
   1. Credit EA 4: Manufacturers’ product data for refrigerants, including printed statement that refrigerants are free of HCFCs.

1.04 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by an Independent Testing Laboratory acceptable to Seattle Code Authorities having jurisdiction and marked for intended use.

B. Fabricate and label refrigeration system to comply with ASHRAE 15, "Safety Code for Mechanical Refrigeration."

D. Coefficient of Performance: Equal to or greater than prescribed by ASHRAE/IESNA 90.1, "Energy Efficient Design of New Buildings except Low-Rise Residential Buildings."

1. ASME Compliance: Fabricate and label water-cooled condenser shell to comply with ASME Boiler and Pressure Vessel Code: Section VIII, "Pressure Vessels," Division 01.

E. Units shall be designed to operate with HCFC-free refrigerants.

1.05 COORDINATION

A. Coordinate layout and installation of room air-conditioning units and suspension system with other construction that penetrates ceilings or is supported by them, including light fixtures, HVAC equipment, fire-suppression system, and partition assemblies.

B. Coordinate installation of computer-room air-conditioning units with computer-room access flooring Installer.

C. Coordinate installation of roof curbs, equipment supports, and roof penetrations. These items are specified in Section 07 72 00, Roof Accessories.

1.06 WARRANTY

A. Warranty Period for Compressors: Manufacturer's standard, but not less than five years from date of Substantial Completion.

PART 2 - PRODUCTS

2.01 UNIT IS SHALL BE SPLIT SYSTEMS MANUFACTURED BY THE SAME MANUFACTURE AND BE PAIRED AS SCHEDULED.

2.02 MANUFACTURERS

A. In other Part 2 articles where titles below introduce lists, the following requirements apply for product selection:

1. Available Manufacturers: Subject to compliance with requirements, manufacturers offering products that may be incorporated into the Work include, but are not limited to, the manufacturers specified.

2.03 CEILING-MOUNTING UNITS

A. Available Manufacturers:

1. Compu-Aire, Inc.
2. IPAC, Inc.
3. Liebert Corporation.
5. Trane Company (The); North American Commercial Group.

B. Description: Self-contained, factory assembled, prewired, and prepiped; consisting of cabinet, fan, filters, and controls; for horizontal ceiling mounting.
C. Cabinet: Galvanized steel with baked-enamel finish, insulated with 1/2-inch-thick duct liner.

D. Evaporator Fan: Forward curved, centrifugal, double inlet and directly driven by two-speed motor.
   1. Motor: Comply with requirements in Section 23 05 13, Common Motor Requirements for HVAC Equipment.

E. Evaporator Coil: Direct-expansion cooling coil of seamless copper tubes expanded into aluminum fins. Mount coil assembly over stainless-steel drain pan.

F. Electric-Resistance Heating Coil: Finned-tube electric elements with contactor, dehumidification relay, and high-temperature-limit switch.

G. Filter: 1-inch-thick, disposable, glass-fiber media.

H. Provide Control Terminals for remote monitoring arranged as shown on building management system plans

I. Control System: All controls shall be set for remote monitoring. Unit-mounted panel with main fan contactor, compressor contactor, compressor start capacitor, control transformer with circuit breaker, solid-state temperature-control modules, time-delay relay, reheat contactor, and high-temperature thermostat. Provide solid-state, wall-mounting control panel with start-stop switch and adjustable temperature set point.
   1. Additional Monitoring:
      a. Monitor constant and variable motor loads.
      b. Monitor variable frequency drive operation.
      c. Monitor cooling load.
      d. Monitor economizer cycles.
      e. Monitor air distribution static pressure and ventilation air volumes.
      f. Common Alarm and Remote on/off
      g. Unit alarm high temperature, low temperature, loss of power, Compressor short cycle.

2.04 AIR COOLED PROP FAN CONDENSING UNIT

A. Compressor: Scroll compressor, with resilient suspension system, oil strainer, and internal motor overload protection.

B. Air-Cooled Condenser: Integral copper-tube aluminum-fin coil with propeller fan, direct driven.

C. High pressure switch and lee temp receiver.

D. Hot gas bypasses circuit for low load conditions.

E. Pre charged refrigerant lines sized as required by drawings. Field verify installation requirements.
F. Condensing unit shall be designed to operate at a sound level less than 58 dBA.

1. Split system shall have suction- and liquid-line compatible fittings and refrigerant piping for field interconnection.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install computer-room air-conditioning units level and plumb, maintaining manufacturer's recommended clearances. Install according to ARI Guideline B.

B. Curb Support: Install and secure roof-mounting units on curbs and coordinate roof penetrations and flashing with roof construction. Secure units to curb support with anchor bolts.

C. Install suspended components level. Coordinate wall penetrations and flashing with wall construction. Secure units to structural support with anchor bolts.

D. Install air-cooled condenser on rubber-in-shear vibration isolators.

E. Install remote glycol cooler on rubber-in-shear vibration isolators.

F. Install glycol pump package on rubber-in-shear vibration isolators.

G. Install floor-mounting units on bases designed to withstand, without damage to equipment, seismic forces required by code.

H. Support suspended units from structure using threaded steel rods and spring hanger, with vertical-limit stop, having 1-inch deflection. Vibration-control devices and installation requirements are specified in Section 23 05 48, Vibration and Seismic Controls for HVAC Piping and Equipment.

3.02 CONNECTIONS

A. Piping installation requirements are specified in other Division 23 Sections. Drawings indicate general arrangement of piping, fittings, and specialties.

B. Install piping adjacent to machine to allow service and maintenance.

C. Refrigerant Piping: Comply with applicable requirements in Section 23 23 00, Refrigerant Piping. Provide shutoff valves and piping.

D. Electrical System Connections: Comply with applicable requirements in Division 26 Sections for power wiring, switches, and motor controls.

E. Ground equipment according Section 26 05 26, Grounding and Bonding for Electrical Systems.

F. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not indicated, use those specified in UL 486A and UL 486B.
3.03 FIELD QUALITY CONTROL
A. Manufacturer's Field Service: Engage a factory-authorized service representative to inspect, test, and adjust field-assembled components and equipment installation, including connections, and to assist in field testing. Report results in writing.

B. Perform the following field tests and inspections and prepare test reports:
   1. Inspect for and remove shipping bolts, blocks, and tie-down straps.
   2. After installing computer-room air-conditioning units and after electrical circuitry has been energized, test for compliance with requirements.
   3. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
   4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

3.04 STARTUP SERVICE
A. Engage a factory-authorized service representative to perform startup service.
B. Verify that computer-room air-conditioning units are installed and connected according to manufacturer's written instructions and the Contract Documents.
C. Verify that electrical wiring installation complies with manufacturer's submittal and installation requirements in Division 26 Sections.
D. Complete installation and startup checks according to manufacturer's written instructions.
E. After startup service and performance test, change filters and flush humidifier.

3.05 ADJUSTING
A. Adjust initial temperature set points.
B. Set field-adjustable switches and circuit-breaker trip ranges as indicated.
C. Occupancy Adjustments: When requested within 12 months of date of Substantial Completion, provide on-site assistance in adjusting system to suit actual occupied conditions. Provide up to two visits to site outside normal occupancy hours for this purpose, without additional cost.

3.06 DEMONSTRATION
A. Engage a factory-authorized service representative to train Sound Transit’s maintenance personnel to adjust, operate, and maintain computer-room air-conditioning units. Refer to Section 01 75 50, System Start-Up and Testing.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes direct digital control (DDC) equipment for tunnel and station ventilation, plumbing, electrical and mechanical systems and components, including control components for units that are not supplied with factory-wired controls. Items to be furnished include control equipment and software programming as well as communications and data transmission equipment and related software programming. This system shall be referred to as the building management system (BMS).

B. Related Sections: The work of the following Sections are 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 22 05 50, Mechanical Identification.

2. Section 26 05 25, Wire and Cable.

3. 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. ASME MC85.1 (American Society of Mechanical Engineers) - Terminology for Automatic Control.

2. IEEE 472 (Institute of Electrical and Electronics Engineers) - Guide for Surge Withstand Capability Test.


4. NEMA IA 2.3 (National Electrical Manufacturers Association) - Programmable Controllers Part 3: Programming Languages (IEC 1131-3)

5. NEMA ICS-1 (National Electrical Manufacturers Association) - General Standards for Industrial Control and Systems.


7. NEMA ICS-2 (National Electrical Manufacturers Association) - Industrial Control Devices, Controllers, and Assemblies.

8. NEMA ICS-4 (National Electrical Manufacturers Association) - Terminal Blocks for Industrial Control.
9. NEMA ICS-6 (National Electrical Manufacturers Association) - Enclosures for Industrial Controls and Systems

10. NFPA 70 (National Fire Protection Association) – National Electrical Code (NEC)


1.03 SYSTEM DESCRIPTION

A. The BMS control processing equipment shall be comprised of one identical pair of chassis, each housing identical PAC modules including: control processors, system redundancy modules, Ethernet I/P modules, ControlNet I/O network modules, and fiber optic communication modules. This layout shall provide fully redundant control and communications for all BMS controlled or monitored equipment and interfaces.

B. In the pair of redundant chassis, the first chassis turned on shall become the primary chassis. When the secondary chassis receives power, it synchronizes itself with the primary chassis.

C. When primary chassis components fail, control switches to the secondary controller. A switchover occurs for any of these reasons:

1. Any of these situations in the primary chassis:
   a. loss of power.
   b. major fault of the controller.
   c. removal, insertion, or failure of any module in the primary chassis.
   d. break or disconnection of a ControlNet tap or Ethernet cable.

2. Command from the primary controller.


D. Control redundancy shall require no additional programming and shall be transparent to any devices connected over an EtherNet/IP or ControlNet I/O network. During the switchover, outputs shall experience a bump-free switchover. For example, outputs are maintained in their current state and do not revert to a previous state.

E. External Monitoring/Control Interface (by Others)

1. Redundancy shall be transparent to the external interface. Provide Ethernet 100BaseT, Modbus/TCP monitoring and control interface on both PAC processors with a single IP address active for the PAC in active control.

2. Switchover to the redundant PAC shall be bump-free for remote interface.

3. Provide a summary PAC warning alarm for all detectable, non-fatal faults in the controller chassis, or IO chassis.

4. Provide a summary PAC fail alarm for major faults including failure of either PAC processor.

F. The BMS I/O processing system shall consist of PAC Chassis supplied by redundant power supplies and equipped with ControlNet I/O network modules, fiber optic communication modules, and appropriate analog and discrete I/O processing modules.
G. Provide fiber optic communication equipment and transmission media, as well as required communication programming, at each location shown on the Plans. Network communications among the individual station control enclosures will be via dedicated fiber optic links. The communication network shall be tolerant of a transmission media break between station control enclosures such that full communications shall be maintained between all enclosures not physically isolated from the network as a result of the break.

H. Provide Human Machine Interface (HMI), equipment, software, and functional programming at the locations shown on the Plans. The HMIs shall be desktop workstations and panel mount, touch-screen displays and shall allow Operator access to all indicated station and tunnel equipment and systems via the same log-in screen and will utilize the same programming and control commands, control software programming languages, and graphical representations. Develop dynamic control and monitoring displays, representing tunnel ventilation, station HVAC, and station plumbing systems and equipment, in close coordination with Sound Transit’s operations and engineering staff. Operator access to the BMS, for the purpose of system manipulation, shall not be allowed from any device other than the dedicated HMI’s.

I. The BMS system shall provide overall system response time meeting the following requirements:
   1. Digital input changes shall be indicated on HMI displays within a maximum of 2 seconds following field device change.
   2. Analog input changes beyond a change detection threshold shall be indicated on HMI displays within a maximum of 5 seconds following field device change.
   3. Digital output commands entered at the workstation or panel-mount terminals shall be executed in the field within a maximum of 2 seconds following command execution.

J. An HMI console workstation shall be provided in the Fire Command Center (FCC) room. This workstation will serve as the Fire Department Emergency Management Console. This console will be connected to the BMS system via an Ethernet/IP local area network (LAN) and will also serve as the operator interface to the various HVAC, plumbing, mechanical, and electrical systems and equipment that is to be controlled or monitored by the BMS. The workstation graphics and functionality shall be programmed in close coordination with Sound Transit as well as the Seattle Fire Department.

K. Provide control equipment and associated software programming at each location shown on the Plans.

L. Contractor shall provide non-proprietary, open standard, communications networks for the use of the BMS system as indicated, and shall provide communication software data to Sound Transit such that, at a future date, additional devices from other manufacturers may be made capable of communicating to the applicable networks.

M. Provide enclosures, sensors, control devices, raceways, conductors and cables, and other components shown on the Plans and as required for complete and fully operational control and monitoring systems.

N. Include installation and calibration, supervision, adjustments, and fine-tuning necessary for complete and fully operational system.

O. The complete system shall be designed for operation under the following environmental conditions. Where the installed location cannot provide the environment required, Contractor shall provide appropriate heat sinks and air tight enclosure to protect the system.
1. Ambient temperature: 0 degree to 60 degree Celsius.
2. Relative humidity: 5 to 95 percent relative humidity.
3. Atmospheric pressure: 795 to 1080 kPa.

P. The BMS control system Contractor shall have the following additional responsibilities under the scope of this contract:

1. Provide submittal and/or record documentation.
2. Provide specified Sound Transit personnel training.
3. Participate in specified commissioning process of related equipment.
4. Perform all system startup and commissioning procedures as required and described by this specification.
5. Respond to project punch list and correct any system deficiencies.

1.04 SUBMITTALS

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

B. System Integrators Qualifications. Submit a printed certified qualification resume of the contractor or systems integrator performing the fabrication, configuration, and programming of the BMS components.

C. Product Data for each type of product specified. Include manufacturer's technical Product Data for each BMS system component furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, installation instructions, and startup instructions.

D. Shop Drawings from manufacturer detailing equipment assemblies or components and indicating dimensions, weights, loadings, required clearances, method of field assembly, and location and characteristics of each field connection.

E. Shop Drawings containing the following information for each BMS control panel and enclosure:

1. Schematic flow diagram showing fans, dampers, and other control devices served.
2. Each control device labeled with setting or adjustable range of control.
3. Diagrams for all required interconnecting wiring. Clearly differentiate between factory-installed and field-installed wiring.
4. Each conductor labeled utilizing identifying labels shown on the Plans.
5. Details of control panel and enclosure faces, including controls, instruments, and labeling.
6. Written description of sequence of operation.
7. Listing of connected data points, including connected control units and input devices.
8. Each data point labeled utilizing unique identifying labels. Use indicated labels where shown on the Plans.
9. Associated Human Machine Interface system graphics indicating monitored systems and devices, data (connected and calculated) point addresses, and operator notations.

10. System configuration showing I/O and peripheral devices, power supplies, diagrams, and interconnections.

11. Software description and sequence of operation.

12. Control Program Listing, fully annotated to describe the function of each programming element and each functional segment.

F. External Monitoring/Control Interface Spreadsheet

1. Provide Excel spreadsheet list of points available for reading and writing by the external interface by others. Include:
   a. Physical IO for discrete inputs, discrete outputs, analog inputs and analog outputs. Include unused spare points.
   b. Logical point for interacting with PAC logic. Include all points needed for external interface to identically simulate real time monitoring/control provided HMI. Note that logical points from external interface to Pac shall be distinct and separate form points to HMI by Contractor.

2. Include the following columns in the spreadsheet for each point:
   a. Point name: unique ID name as used in PAC logic
   b. Point Description: Brief functional description as used in PAC logic
   c. On State: For discrete point, the meaning of the point when it’s On
   d. Off State: For discrete points the meaning of the point when it’s Off
   e. Analog Range: For analogs X/Y where S and Y are the low and high engineering units range of the analog
   f. Discrete Alarm: Defines whether the point is in alarm when On or Off. Enter None if no alarm
   g. Modbus/TCP address of the point
   h. Physical Reference: For real IO, a reference to Contractor provided documentation for the wiring drawing
   i. Functional Reference: For control related points, a reference to Contractor provided documentation describing how the logical functionality of the point.

G. Wiring diagrams detailing wiring for power, signal, and communications systems and differentiating clearly between manufacturer-installed and field-installed wiring.

H. Training Plan: Procedures and materials to be used for BMS system operator and maintenance training. Submit for approval at least 30 days prior to anticipated commencement training.

I. Commissioning Plan: Procedures and certification of BMS system functionality. Submit for approval at least 30 days prior to commencement of formal testing.
J. External Monitoring/Control Interface Validation Test Procedures

K. Completed External Monitoring/Control Interface Validation Test Results

1.05 CLOSEOUT SUBMITTALS

A. Refer to Section 01 33 00, Submittals, for submittal requirements and procedures.

B. Project Record Documents: Record actual locations of control components, including all field components and sensors. Revise Shop Drawings to reflect actual installation and operating sequences. Include all data specified in "Submittals" in final "Record Documents" form.

C. Operation and Maintenance Manuals: Contractor shall furnish an operation and maintenance manual for each piece of equipment, unless otherwise specified herein. The following identification shall be inscribed on the cover: the words "OPERATING AND MAINTENANCE MANUAL", the name and location of the project, the name of Contractor, and the Contract number. The manual shall include the names, addresses, and telephone numbers of each subcontractor furnishing or installing equipment, and of the local manufacturer's representatives for each item of equipment. The manual shall have a table of contents and be assembled to conform to the table of contents with the tab sheets placed before instructions covering the subject. The instruction sheets shall be legible with large sheets of drawings folded in. The manuals shall include all approved shop drawings, catalog cuts and test reports.

1. Contractor shall submit for acceptance, at least 30 days before shipment of first relevant unit, two copies of the preliminary operation and maintenance manual that shall provide technical support for BMS equipment operation and maintenance. After acceptance of the preliminary submittal and having made all necessary corrections and amendments required, Contractor shall provide 5 additional copies of the accepted dated operation and maintenance manuals. In addition, one set of master camera-ready loose leaf copy shall be included to permit additional copies to be made. The manual shall provide a clear explanation of the theory, operation, and maintenance of the equipment accompanied by photos and schematic, wiring and mechanical assembly diagrams, as required. The manual shall be indexed and cross-referenced in an easily understood manner. The manual shall be loose leaf bound and shall include, but not necessarily be limited to, the following information:

   a. Operating instructions.
   b. Troubleshooting and fault isolation procedures for on-site level repair.
   c. Workstation, HMI, and PAC equipment replacement procedures.
   d. Disassembly and reassembly instructions.
   e. A list of the components that are replaceable at the three possible levels of maintenance: on site, department shop, and the manufacturer's facility.
   f. A test procedure to verify the adequacy of repair work.
   g. A preventive maintenance schedule and instructions for the replacement of any electrical equipment, e.g., I/O cards, software, controller cards, etc.
   h. A preventive maintenance schedule for inspection, removal, and replacement for each component.
   i. A list of special tools provided by the manufacturer.
j. A list of recommended tools and test equipment required to perform all maintenance tasks.

k. Recommended spare parts list for one year's operation.

l. Interchangeable parts list showing parts common to items of equipment.

m. Equipment manufacturer's descriptive literature including catalog cuts.

n. Record drawings.

o. The latest service bulletins, with issue dates, that describe service procedures.

p. The Workstation, HMI terminal, and PAC software source programs as well as trouble shooting, fault diagnostics, and shutdown procedures.

q. Computer software: Hard and electronic copies of the PAC application source code, data table allocations, and descriptions of main software modules.

D. Training materials for BMS system operation and maintenance training sessions as specified herein.

E. Final Commissioning report and test manual.

1.06 TRAINING

A. The Contractor shall be responsible for training coordination and scheduling and for ensuring that training is completed on all equipment per the specifications.

B. Sound Transit's operating and maintenance staff shall comprehensive receive orientation and training, to include: Training on all modes, functions, operations and maintenance of all features, systems, and equipment as a provided by this project and as defined and outlined herein.

1.07 QUALITY ASSURANCE

A. Installer Qualifications: Engage an experienced Installer specializing in control system installations with minimum three years documented experience, and approved by the BMS system manufacturer.

B. Manufacturer Qualifications: The DDC hardware shall be furnished by a single vendor who has actively been manufacturing programmable controllers of the required capabilities and whose products have operated successfully for a period of at least five years. The programmable controller manufacturer or the manufacturer's approved system integrator, shall maintain as part of a national network, engineering service facilities within 150 miles of the Project, to provide start-up service, emergency service calls, repair work, service contracts, maintenance, and training of personnel. Emergency service shall be available within 24 hours of notification. At Engineer's request, provide a listing of at least five projects of similar magnitude, complexity and facility use type completed within the past five years.

C. System Integrator Qualifications: The contractor or integrator shall have a minimum of 5 years experience related to design, fabrication, programming, installation, start-up, and testing of similar DDC control systems. If more than one contractor or systems integrator is employed, provide a certified resume for each one indicating their specific specialty and item of work.
D. Commissioning/Startup Personnel Qualifications: Where necessary, engage specially trained personnel in direct employ of manufacturer of BMS control system components.

1.08 FACTORY TESTS AND INSPECTIONS

A. General:

1. The following specifies the testing requirements for the workstation console, PAC equipment, and panel-mounted HMI terminals to be procured under this Contract. All tests described herein shall not preclude any additional standard tests normally performed by the manufacturers for similar equipment or requested by the Engineer to verify performance.

2. Contractor shall notify the Engineer in writing of all scheduled test dates not less than 14 days before proposed start date. The notification shall include the expected duration and sequence of testing. Observations made during the tests, and test results shall be recorded in a document form acceptable to the Engineer, certified by Contractor and submitted to the Engineer for record before shipping equipment to site. All expenses in connection with or incidental to the testing shall be borne by Contractor excluding Engineer travel expenses.

3. The test procedure specified shall be sequential in the order prescribed. Workstation console, PAC, communications equipment, or any components, which failed to perform as specified, shall be subject to retest at no addition cost to the Agency.

B. Workstation Console and Programmable Automation Controller (PAC) system:

1. Arrange for factory testing of Workstation Console and PAC system. Tests shall be witnessed and unwitnessed as determined by the Engineer.

2. Witnessed Tests (as minimum): Workstation Console, PAC system, and HMI Terminals, shall be tested for operation, sequencing, inter-locking, communications, diagnostics, fault conditions, data logging and alarming functions as outlined in this Specification and the Drawings. All field functions shall be simulated in the factory for the purpose of this test.

3. Unwitnessed factory tests and checks shall include:

   a. Check of control and power wiring insulation resistance and freedom from shorts and grounds.

   b. All assemblies and components used in the Workstation Console and PAC systems shall be proven with equipment type testing including, but not limited to:

      1) Production and conformance tests in accordance with the relevant specified standards.

      2) Temperature cycling tests.

      3) Dielectric withstand capability tests.

      4) Radiated and conducted electromagnetic susceptible tests.

      5) Mechanical Stress Tests:

          a) Vibration.
b) Shock.

c) Free fall at height of three feet.

c. Workstation Console and all PAC system components shall be subjected to a burn-in test at 60 degrees Centigrade for at least 96 hours.

4. External Monitoring/Control Interface Validation Testing

a. Prepare test forms for all points on the accepted External Interface Spreadsheet.

b. Add “Validated” column to the spreadsheet for witness initials and witnessed date of successful demonstration of the point.

c. Demonstrate correct demonstration of IO and related functionality to Sound Transit representative in the field.

d. Demonstrate points through actual operation of equipment. Demonstration by simulation of as accepted by the Resident Engineer.

e. For testing convenience provide tables of the real and logical points in the HMI to easily verify the actual state of each point.

1.09 FIELD MEASUREMENTS

A. Verify field measurements and clearances prior to fabrication and installation of BMS system components

1.10 MAINTENANCE SERVICE

A. During the warranty period provide a 24-hour emergency service number where a qualified automation service engineer familiar with the installed system may be reached.

1.11 POWER LINE SURGE PROTECTION

A. Equipment connected to ac circuits shall be protected from power-line surges. Equipment protection shall meet the requirements of IEEE C62.41. Fuses shall not be used for surge protection.

1.12 DELIVERY, STORAGE, AND HANDLING

A. Store equipment and materials inside and protected from weather and other hazards.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. PAC Equipment

1. Allen-Bradley ControlLogix Platform

2. Approved Equal

B. Fiber Optic Communications Equipment

1. Phoenix Digital
2. Approved Equal

C. Human Machine Interface Units (HMI), Console
   1. Dell
   2. Approved Equal

D. Enclosure and Panels
   1. Hoffman
   2. Carlon
   3. Circle AW
   4. Approved Equal

2.02 SYSTEM CONTROL EQUIPMENT DESCRIPTION

A. Operator Interface Unit (HMI), Console Workstation: Microcomputer station with printer.
   1. Workstation: IBM-compatible microcomputer with minimum configuration as follows:
      a. Processor: Intel Core 2 Quad.
      b. Random-Access Memory: 4 GB, Dual-Channel, Non-ECC.
      c. Graphics: High Performance, PCI Express x16, 768 MB DDR memory, 1920x1200 @ 70 Hz Maximum Resolution.
      d. Monitor: 21-inch, widescreen, color LCD.
      e. Keyboard: QWERTY.
      f. Hard Disk Drive: 500.0 GB, SATA.
      g. Mouse: 3 button optical.
      h. Operating System: Microsoft Windows, most current version.
   2. Printer: Color Ink Jet type.
   3. Application Software: Include the following:
      a. Input/output capability from operator station.
      b. Operator system access levels via software password.
      c. Database creation and support.
      d. Dynamic color graphic displays.
      e. Alarm processing.
      f. Event processing.
      g. Automatic restart of field equipment on restoration of lost power.
      h. Data collection, storage, and historical trending.
i. Graphic development on workstation.

j. Maintenance management.

B. Human Machine Interface (HMI), Panel-Mount Terminal:

1. 5.5" (diag) Color Active Matrix Thin Film Technology (TFT).
2. 320 x 480 pixel resolution, 18-bit color graphics.
3. Touchscreen and Function Keys (10) operator input.
4. 64 MB flash memory/64 MB RAM memory.
5. Supply Power: 120 VAC
6. NEMA 4X rated when installed per manufacturer’s recommendations.
7. Programmed to provide the following:
   a. Input/output capability from operator station.
   b. Operator system access levels via software password.
   c. Dynamic color graphic displays.
   d. Alarm processing.
   e. Event processing.

C. Control Units: Modular, comprising redundant microprocessor-based central processor unit modules with programmable, nonvolatile, random-access memory; power supply modules; system redundancy modules, input/output communications network processing modules, and system communications modules.

1. Units monitor or control each input/output point; process information; execute commands from operator terminals or LCC operators; and download data from or upload data to HMI units.
2. Control Units shall be equipped with web server capability to provide control and status information to web-browser-based applications.
3. Control functions operate, regardless of system communications network status, over redundant fiber optic I/O network communication links. Functions include the following:
   a. Global I/O communications.
   b. Discrete/digital, analog, and pulse input/output.
   c. Monitoring, controlling, or addressing data points.
4. Global System Communications:
   a. Broadcast point data onto Ethernet/IP network, making that information available to all other operator terminals.
5. Each BMS control enclosure and control panel shall be provided with an RS-232C serial data communication port for operator I/O devices such as industry standard portable operators terminals or portable lap-top computers.

6. Each BMS control panel shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all subsidiary equipment. Information concerning detected diagnostic faults shall be broadcast network-wide via the I/O network.

7. All necessary software to form a complete operating system as described in this specification shall be provided. Applicable software programs shall be provided as an integral part of each BMS panel and shall not be dependent upon any higher-level computer for execution.

8. Provide Uninterruptable Power Supplies (UPS) for each BMS panel. UPS shall be capable of powering the DDC panel for a minimum of 5 minutes and protecting the control equipment from a restart in the event of a momentary power outage or switchover to alternate power source.

9. Sensor and Control Wiring Surge Protection: Controllers shall have sensor and control wiring surge protection with optical isolation, metal oxide varistors (MOV), or silicon avalanche devices. Fuses are not permitted for surge protection.

D. BMS System Communications Network (LAN):

1. System Support: Capacity for a minimum of 4 HMIs connected to multi-user, multitasking environment with concurrent capability to access BMS network or control units.

2. Ethernet/IP communications protocol at minimum transmission rate of 100-Base-T.


4. Fiber optic communication modules that provide fault-tolerant, self-healing communication path via redundant fiber media. Fault locating and reporting with online error checking and interactive diagnostics accessible network-wide.

E. Software: Update to latest versions of software at project completion. Include and implement the following capabilities:

1. Software shall be developed to provide the control units with the functionality specified herein and on the Plans.

   a. Automatic response of tunnel ventilation system to fire alarm system event signaling. Automatic response shall be programmed with an operator adjustable initiation delay time (initially set to 90 seconds) to accommodate Seattle Fire Department policies on automatic response.

   b. Operator initiated response of station smoke ventilation system following a tunnel ventilation system event.

   c. Automatic operation of station HVAC, plumbing, mechanical, and electrical systems during both normal and emergency events.

   d. Operator selectable ventilation system operating modes, as indicated in the Equipment Operation Matrices.

   e. Manual (operator initiated) selection and control of individual HVAC, plumbing, and mechanical system components.
f. Monitoring and controlling of indicated field equipment and devices.

2. Software shall be developed to provide the HMI units with the functionality specified herein and on the Plans.
   a. Input/output Capability From Operator Station:
      1) Request display of current values or status in tabular or graphic format.
      2) Command selected equipment to specified state.
      3) Initiate logs and reports.
      4) Change analog limits.
      5) Add, delete, or change points within each control unit or application routine.
      6) Change point input/output descriptors, status, alarm descriptors, and engineering unit descriptors.
      7) Add new control units to system.
      8) Modify and set up maintenance scheduling parameters.
      9) Develop, modify, delete or display full range of color graphic displays.
      10) Automatically archive select data even when running third party software.
      11) Provide capability to sort and extract data from archived files and to generate custom reports.
      12) Support alarm/data printer operations.
         a) Print alarms, operator acknowledgments, action messages, system alarms, operator sign-on and sign-off.
         b) Print reports, page prints, and data base prints.
      13) Operator selectable output of screen graphical images, data trend logs, and/or alarm summary information to printer.
      14) Automatic time and date stamped output of all system alarms and automatic or manual control system actions to printer.
      15) Select daily, weekly or monthly as scheduled frequency to synchronize time and date in digital control units. Accommodate daylight savings time adjustments.
      16) Print selected control unit database.
   b. Dynamic Color Graphic Displays:
      1) Utilizes custom symbols or system supported library of symbols.
      2) Sixty outputs of real-time live dynamic data per graphic.
3) Dynamic graphic data.
4) Up to 1,000 separate graphic pages.
5) Modify graphic screen refresh rate between 1 and 60 seconds.

c. Graphic screens to be developed in conjunction with Sound Transit staff include but are not limited to:

1) Overview of entire tunnel and station ventilation system, providing means to quickly select specific equipment or system graphics and indicating critical system-wide operating parameters and alarms.

2) Overviews of each ventilation, plumbing, or mechanical system, providing means to quickly select specific graphics and indicating system-wide operating parameters and alarms.

3) Graphical representation of ventilation equipment configuration at each specific station location, indicating status of each ventilation system component.

4) For each tunnel or station system, provide screens showing user-configurable historical data trend logging of equipment status and monitored signal values.

5) System-wide alarm summary screen indicating date, time, and nature of alarm event and providing the means to quickly select the graphical representation screen pertaining to the affected equipment or system.

6) Communications network overview screens indicating status and diagnostic information generated by the system communications and I/O communications network sub-systems.

d. Operator System Access: Via software password with minimum 10 access levels at HMI.

e. Data Base Creation and Support: Changes shall utilize standard procedures. Control unit shall automatically check workstation data base files upon connection and verify data base match. Minimum capability shall include:

1) Add and delete points.
2) Modify any point parameter.
3) Change, add, or delete English language descriptors.
4) Add, modify, or delete alarm limits.
5) Add, modify, or delete points in start/stop programs, trend logs, etc.
6) Create custom relationship between points.
7) Create or modify DDC loops and parameters.
8) Create or modify override parameters.
9) Add, modify, and delete any applications program.

10) Add, delete, develop, or modify dynamic color graphic displays.

f. Alarm Processing:

1) Abnormal condition: Cause alarm and appropriate message, including time, system, point descriptor, and alarm condition.

2) Critical alarm or change-of-state: Display message, stored on disk for review and sort, or print.

3) Print one line changeable message, up to 40 characters in length, for each alarm point specified.

4) Display alarm reports on video. Display multiple alarms in order of occurrence.

5) Define time delay for equipment start-up or shutdown.

6) Allow unique routing of specific alarms.

7) Operator selectable configuration specifies if alarm requires acknowledgment.

8) Continue to indicate unacknowledged alarms after return to normal.

9) Alarm notification:

10) Print automatically.

11) Display indicating alarm condition.

12) Selectable audible alarm indication

2.03 CONTROL PANELS

A. BMS Control Enclosures: Provide wall-mounted, single door, enclosures rated ICS 6, NEMA Type 12 and 13. Enclosures shall, as a minimum, be constructed of 16 gauge steel with all seams continuously welded and smoothly finished, and shall possess integral, rolled lip framing around the door to prevent dirt, water, and other debris from falling into the cabinet when the door is opened. Enclosure door shall be fully gasketed with glued-in-place oil resistant gaskets and shall be equipped with a screwed-down door clamp mechanism and padlockable hasp assembly. Exterior finish shall be cabinet manufacturer's standard corrosion inhibiting, baked-on enamel finish over phosphatized surfaces. The enclosure interior surfaces and back panels shall be finished with the cabinet manufacturer's standard corrosion-inhibiting, white high-gloss baked-on enamel finish.

B. Fan/Damper Control Panels: Provide wall-mounted, continuous hinge, single door, enclosures rated ICS 6, NEMA Type 12 and 13. Enclosures shall, as a minimum, be constructed of 16-gauge steel with all seams continuously welded and smoothly finished. Enclosure door shall be fully gasketed with glued-in-place oil resistant gaskets and shall be equipped with a screwed-down door clamp mechanism and padlockable hasp assembly. Enclosure exterior and interior finishes shall be cabinet manufacturer's standard corrosion inhibiting, baked-on enamel finish over phosphatized surfaces.
2.04 CONTROL PANEL INTERNAL COMPONENTS

A. Fiber Optic Patch Panels: Provide surface mount telecommunications outlet housings of a high-density, low-profile, design with four field-configurable ports, snap-lock cover, and cable knockouts on back. Base shall include tie-wrap anchor points at all cable entrances. Housings shall be mountable with screws and have mounting holes that are compatible with standard NEMA wall boxes. Constructed of high-impact self-extinguishing plastic. UL listed.

B. Terminal Blocks: Provide channel mounted, impact and combustion resistant, self-extinguishing type terminal blocks. Terminal blocks shall be rated, as a minimum, for continuous operation at 10 A Ac at 600 V AC. Terminals shall be of the tubular screw clamp type and shall be capable of accommodating two #14 AWG or one #12 AWG conductors of the type specified herein. Furnish all required end plates, channel clamps, separators and other components required for installation in accordance with the manufacturer's recommendations. Terminal blocks shall each be equipped with an appropriate label which is large enough to legibly accommodate identifying numbers as shown on the Plans.

C. Channel Mounted Circuit Breakers: Provide units equipped with "tripped" indication, rated as specified in the Plans. Channel mounted breakers shall mount on the same size and type of mounting channel as the terminal blocks specified herein and shall possess terminals each capable of accommodating one #14 AWG wire of the type specified herein. Each breaker shall be equipped with an appropriate label and labeling space large enough to legibly accommodate a three-digit identifying number. Provide thermal-magnetic type circuit breakers with a "normal blow" tripping characteristic curve.

D. Wireway: Provide slotted type plastic wireways, with covers, of the size specified in the Plans and as required for neat installation of interconnecting conductors. Wireways shall be restricted slot type to prevent accidental removal of wires and shall be constructed of rigid, non-flammable polyvinyl chloride (PVC). Wireway shall be UL recognized for continuous operation at 120 °F.

E. 24VDC Power Supplies: Provide regulated 24 volt DC power supplies as shown on the Plans.

2.05 UNINTERRUPTABLE POWER SUPPLY (UPS)

A. The UPS shall provide power conditioning, both voltage regulation and noise rejection. The power conditioning section shall be of the ferro-resonant design, with no moving parts and no tap switching while electrically isolating the secondary from the power-line side. Characteristics of the power conditioning section shall be as follows:

1. At 85 percent load, the output voltage shall not deviate by more than plus or minus 13 percent of nominal when the input voltage fluctuates between minus 20 percent to plus 10 percent of nominal.

2. During load changes of zero to full load, the output voltage shall not deviate by more than plus or minus 3 percent of nominal. Full correction of load switching disturbances shall be accomplished within 5 cycles, and 95 percent correction shall be accomplished within two cycles of the onset of the disturbance.

3. Total harmonic distortion shall not exceed 3-1/2 percent at full load.

B. The UPS shall be sized as shown on the Plans.

2.06 CONTROL CABLE

A. Electronic Cable for Control Wiring: Refer to Section 26 05 25, Wire and Cable.
PART 3 - EXECUTION

3.01 SEQUENCE OF OPERATION

A. The BMS System shall be programmed to operate mechanical and electrical ventilation, HVAC, and plumbing system components according to sequences of operation indicated on the Plans and specified herein and in related Sections.

B. The HMI shall dynamically display the current status or position of each item of equipment. Available status information shall be as shown on the Plans and indicated herein.

C. Normal Operation:
   1. The HMI indicates ‘Normal’ system status.
   2. Ventilation, HVAC and plumbing systems operate according to their normal sequence of operations.
   3. The operator may, at any time, select from any of the ventilation controls operating modes identified in the Equipment Operation Matrix shown on the Plans and initiate ventilation system operations.
   4. Selection of an operating mode causes the HMI to provide a graphical description of the affected tunnel segments, the operating mode (exhaust or supply) and operating speed of each fan, the anticipated positions of each ventilation damper, and the expected tunnel airflow direction.

D. Tunnel Incident Response (initiated by input from the Fire Alarm Control Panel (FACP) or by LCC operator):
   1. The Fire Alarm system generates a zone specific serial message of a detected event within the tunnel.
   2. The BMS receives the indication from the FACP and provides a color change indication of the affected tunnel zone on the BMS HMI’s.
   3. The BMS determines the proper equipment operating configuration based on the Equipment Operation Matrix shown on the Plans and informs the Operator console of the recommended configuration. Following the operator adjustable time delay, the BMS automatically starts the ventilation fans in the required mode (exhaust or supply) and operating speed, and correctly positions each ventilation damper.
   4. The tunnel event response operating configuration determined by the BMS shall be displayed on each HMI and shall clearly indicate all equipment operation status and position as well as the intended ventilation airflow direction.
   5. Complete and correct ventilation fan and damper operation and adequate duct airflow are verified by field device feedback and indicated by dynamically changing symbols and numeric values on the BMS HMI’s.
   6. The Control System maintains each item of equipment in its response state until confirmation is received from the on-scene incident response commander that the smoke/fire event has been ‘Cleared’.
7. Upon receipt of confirmation of event ending, the BMS operator returns all ventilation fans to the ‘Off’ state, and all dampers to their normal position.

E. Station Incident Response (initiated by input from the Fire Alarm Control Panel (FACP)):

1. The Fire Alarm system generates a zone specific serial message of a detected event within the station.

2. The BMS receives the indication from the FACP and provides a color change indication of the affected station zone on the BMS HMI’s.

3. The BMS determines the proper ventilation, HVAC, and station equipment operating configuration based on the applicable sequence of operations shown on the Plans and in the related Sections, and informs the Operator console of the determined configuration. The BMS automatically posture the station systems and equipment in the required configuration.

4. The Control System maintains each item of equipment in its response state until confirmation is received from the on-scene incident response commander that the smoke/fire event has been ‘Cleared’.

5. Upon receipt of confirmation of event ending, the BMS operator returns all ventilation, HVAC, and station equipment to their normal operating configurations and states.

F. Abnormal Operation:

1. Each item of equipment shall be monitored via device feedback to ensure correct operation. Failure of equipment to respond correctly within the timeout period limits prescribed on the Plans and herein, shall result in the following actions:
   
a. An alarm message shall be displayed on the HMI and annunciated to the Operator via an audible alert. The message shall indicate the specific equipment, device and nature of the alarm.

b. The Incident Response sequence for all other equipment and devices, as stated above, remains unchanged.

2. Failure to detect adequate duct airflow, via flow (differential pressure) switch feedback, shall result in the following actions:
   
a. An alarm message shall be displayed on the HMI and annunciated to the Operator via an audible alert. The message shall indicate the specific location of the failed detection.

b. The Incident Response sequence for all other equipment and devices, as stated above, remains unchanged.

3. Each ventilation fan/motor combination shall be monitored, via device feedback, for temperature and vibration levels. High Temperature and High Vibration events shall result in the following Control System actions:
   
a. An alarm message shall be displayed on the HMI and annunciated to the Operator via an audible alert. The message shall indicate the specific location and nature of the event detected.

b. Motor/Fan operation shall not be halted by detection of temperature or vibration events.
4. Each local passenger platform shall be monitored, via continuous transducer feedback, for pressure differential with respect to the stairways and elevator shafts. High pressure differential during attempted passenger emergency egress may result in the inability of emergency doors to be opened. During the Incident Response sequence, pressure differential levels exceeding the levels prescribed on the Plans and herein shall result in the following actions:

a. An alarm message shall be displayed on the HMI and annunciated to the Operator via an audible alert. The message shall indicate the specific location and value of the detected pressure differential.

b. Appropriate motorized dampers shall be operated to reduce the pressure differential below the prescribed levels.

3.02 EXAMINATION

A. Verify that conditioned power supply is available to control units and operator workstation. Verify that field end devices and wiring are correctly and securely installed before proceeding with installation.

3.03 INSTALLATION

A. Install equipment as indicated to comply with manufacturer’s written instructions.

B. Install software in control units and operator workstation. Implement all features of programs to specified requirements and appropriate to sequence of operation.

C. Connect and configure equipment and software to achieve the sequence of operation specified.

D. Verify location of exposed control sensors with plans and structural details before installation. Locate 60 inches above floor.

E. Install labels and nameplates to identify control components according to Section 22 05 50, Mechanical Identification.

3.04 ELECTRICAL WIRING AND CONNECTIONS

A. Install raceways, boxes, and cabinets according to Section 26 05 33, Raceways and Boxes, for Electrical Systems.

B. Install building wire and cable according to Section 26 05 25, Wire and Cable.

C. Install signal and communication cable according to Section 26 05 25, Wire and Cable.

D. Install all cables and conductors in raceway.

E. Conceal raceway, except in mechanical rooms and areas where other conduit and piping are exposed.

F. Bundle and harness multi-conductor instrument cable in place of single cables where a number of cables follow a common path.

G. Fasten flexible conductors, bridging cabinets and doors, neatly along hinge side; protect against abrasion. Tie and support conductors neatly.

H. Label all control conductors, utilizing identifying labels shown on the Plans, for future identification and servicing of control system.
I. Connect electrical components to wiring systems and to ground as indicated and instructed by manufacturer. Tighten connectors and terminals, including screws and bolts, according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torquing requirements are not indicated, tighten connectors and terminals according to tightening requirements specified in UL 486A.

3.05 FIELD QUALITY CONTROL

A. Signal Integrity: Checks shall be implemented as part of the Pre-Commissioning Checklist to verify interconnections between the BMS system and the field instruments and devices. All signal interconnections shall be individually physically verified for proper terminations and noted on the Pre-Commissioning Checklist. Completed checklist shall be submitted as part of the final test report.

3.06 COMMISSIONING

A. Develop a Commissioning Plan that details the implementation of the commissioning process for the BMS system and includes the following elements:

1. Detailed definition of responsibilities, accountabilities, and deliverables by each party within the commissioning process.

2. System and equipment commissioning scope of work list.

3. Pre-Commissioning Checklist: Procedure and certification to provide individual verification of all installed system components. Verify that submittal information and installed components match. Review complete system installation, cleaning, and initial settings and verify that system is ready for operations.

4. Pre-Operation Checklist: Procedure and certification to provide verification, by system or equipment, of system setpoints, operating strategies, and required pre-operational component adjustments and testing such as correct fan rotation and damper operation.

5. Functional Performance Test Plan: Test plans shall include a test calendar, a detailed sequence and schedule, and a step-by-step procedural description of all required tests which clearly indicates planned actions and the anticipated corresponding equipment response or sequence of responses. Test plans shall include a comprehensive ventilation system component and equipment list that provides a test verification signoff field for each item. Performance tests shall verify that all components, sub-systems, and systems comprising the BMS system function in accordance with the Contract Documents.

6. Acceptable System Performance Standards: Definition of test durations, test criteria, and acceptable operational functionality and performance criteria for each of the planned functional tests.

7. Training Plan: Plans for both operator’s training and maintenance personnel training shall include proposed training schedules along with detailed descriptions of all course contents and training materials. Training plans shall clearly indicate training objectives and shall outline anticipated means of achieving stated objectives. Develop training objectives and a format for the training plan and agenda after meeting with appropriate Sound Transit facility and maintenance staff to determine needs and areas of emphasis for this project.

B. Manufacturer’s Field Services: Provide the services of a factory-authorized service representative to assist in commissioning of DDC systems.
C. Contractor to replace, at no cost to Sound Transit, all controls and equipment found to be damaged, malfunctioning, or that does not meet acceptable system performance standards. Submit a corrective action plan for all noted deficiencies identified during the commissioning process.

D. Final Commissioning report and test manual: Provide BMS system final commissioning report and test manual as part of the Operation and Maintenance manuals specified herein.

3.07 TRAINING

A. Provide training for a minimum of eight Sound Transit Employees as follows:

1. Training in the receipt, handling, and acknowledgment of alarms.

2. Training in BMS operation including logging-in, manipulating setpoints and limits, navigating HMI graphical screens, and the initiation of both automatic and manual control output actions from the BMS HMI’s.

3. Training in BMS functional operation and monitoring of each ventilation, HVAC, plumbing, and electrical system within the University of Washington Station. Training to include complete overview of system operation and available operating modes and parameters.

4. Training on trending, archiving, and report generation using data points available within the BMS.

5. Maintenance training covering each aspect of preventative maintenance, emergency repair, and control unit and HMI programming development and modification.

3.08 SPARE PARTS

A. All spare parts shall conform to the requirements of Part 2, Products, of this section.

B. Provide the indicated quantity and type of new spares, in original unopened packaging, to enable the replacement of the following components in the event of a failure:

C. Six of each type of fuse used within the BMS system.

D. Two of each type and rating of relays and contactors used.

E. Three of each type of relay/contactor/module socket base used.

1. Two of each type and rating of channel mounted circuit breakers used.

2. Two of each type of PAC processor, I/O, communications and power supply module used.

END OF SECTION
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## APPENDIX A

### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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<th>POINT ID</th>
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## APPENDIX A

### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A

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# APPENDIX A

## BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A

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## APPENDIX A

### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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# APPENDIX A  BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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### APPENDIX A

#### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A

### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A  BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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BUIDLING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A

### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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# APPENDIX A

## BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A

### BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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## APPENDIX A BUILDING MANAGEMENT SYSTEM I/O POINT LIST

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SECTION 26 05 00
COMMON WORK RESULTS FOR ELECTRICAL

PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for wiring devices, disconnect switches, fuses, and control relays.

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 (NECA):
   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. Underwriter’s 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. Procedure: Section 01 33 00, Submittal Procedures.

B. List of Materials: At least 30 days before beginning the work of this Section, 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 or listing of the specified agency will be acceptable evidence.
   3. Instead of the label or listing, the Contractor may submit a written certificate from an approved, nationally recognized testing organization, adequately equipped and competent to perform such services, stating that the items have been tested and that the units conform to the specified standard.

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 Contract. Include wiring and control diagrams.

E. Shop Drawings: Submit shop drawings showing equipment layouts and fabricated work being provided under these Specifications. Submit such drawings before rough-in work, fabrication, and within ample time to prevent delays in the Work. Include electrical diagrams for equipment and equipment installation.

F. Field Test Reports: Submit certified field test reports of field tests, verifying compliance of equipment and systems with Specification requirements.

G. 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. Include recommended maintenance materials and spare parts list for installed equipment.

1.04 QUALITY ASSURANCE

A. Qualifications: Ensure workers performing work 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.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Furnish materials and equipment of design, sizes, and ratings as indicated and suitable for the intended purpose.

B. 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.

C. Methods of fabrication, assembly, and installation are optional unless otherwise indicated.

D. Provide products that are free from defects, which may impair performance, durability, or appearance.

E. 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.

2.02 COMPONENTS

A. SWITCHES
   1. Provide ac, tumbler-type toggle switches conforming to minimum requirements of NEMA WD 1, heavy-duty general use type.
2. Provide switches that operate in any position and are fully enclosed with entire body and cover of molded phenolic, urea, or melamine. Do not use fiber, paper, or similar insulating material for body or cover.

3. Equip switches with metal mounting yoke with plaster ears, insulated from the mechanism and fastened to the switch body by bolts, screws, rivets, or other substantial means.

4. Provide the section of the yoke normally intended to bear on the surface outside the box with a minimum over-all dimension of 3/4 inch, measured at right angles to the longitudinal axis of the yoke.

5. Use switch contacts of silver or silver alloy.

6. Use switches that are back or side wired with terminals of screw or combination screw-clamp type.

7. Use terminal screws No. 8 or larger, captive or terminal type.

8. For switches to be used on incandescent or fluorescent lighting circuits use fully-rated 20 A at 120 V or 277 V.

9. Switches controlling straight resistance loads may be snap switches as specified herein, of the proper rating up to 30 A at 120-277 V.

10. Provide 120-277 V ac snap switches capable of withstanding tests as outlined in NEMA WD 1. If requested by the Resident Engineer, submit evidence that the types of switches proposed have satisfactorily withstood these tests.

B. RECEPTACLES

1. Receptacle Standards: Ensure connector and outlet receptacles 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.


4. GFCI Receptacles: For ground fault circuit interrupter (GFCI) duplex receptacles use 120 V, 60 Hz, 20 A with built-in test, reset buttons, and ground fault tripped indication. Ensure they interrupt 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 the circuit. Circuit capacity for the latter is 20 A. Furnish receptacles with necessary wire connectors, clips, mounting screws, and instructions.
5. Clock Receptacles:
   a. Provide grounding receptacles for clocks, recessed so that male cap will be flush with the wall to permit the clock to cover the outlet.
   b. Provide plates, including finishes, as specified for cover plates, adapted to the recessed receptacles and with substantial hooks to support the clocks.

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 rain cover where required or as indicated.
   6. Public Area outlet boxes and covers shall be duplex receptacle, hinged locking cover, stainless steel outlet boxes. The outlet boxes and covers shall be rated for a harsh environment and be made of Type 302 stainless steel with a gasketed cover. The lock cylinder will be furnished under Section 08 71 00.

D. 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.
   E. Conform to the seismic restraint requirements of the International Building Code and Washington State Building Code. Ensure electrical equipment installed under these
Specifications conforms to IBC Section 1621, Architectural, Mechanical, and Electrical Component Seismic Design Requirements.

F. Control erection tolerance requirements so as to not impair the strength, safety, serviceability, or appearance of the installations.

G. Install switches, receptacles, special purpose outlets, and cover plates complete in accordance with NECA 1, the National Electrical Code, and local electrical codes.

H. Seal equipment enclosures against dust, whenever dusty conditions are present inside the rooms or outside, during the construction period.

3.02 CONSTRUCTION

A. WIRING

1. Provide wiring systems complete as indicated and required for proper service. Provide ample slack wire for motor loops, service connections, and extensions. In outlet or junction boxes provided for installation of equipment by others, tape ends of wires and install blank covers.

B. 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.

C. INTERFACE WITH OTHER WORK

1. Coordinate the work of this Section with the other Sections of this Division 26, Electrical, as required to provide a complete and operable electrical installation.

2. Coordinate electrical services and work with the serving utility company and the Resident Engineer, as applicable.

3. 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.
4. Contract Drawings show electrical equipment, ductbanks, raceways, and other electrical facilities diagrammatically and do not show all accessories or fittings that may be 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
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing dry-type transformers.

1.02 REFERENCES
A. This Section incorporates by reference the latest revision of the following documents.
   1. National Electrical Manufacturers Association (NEMA):
      a. NEMA ST 20 Dry Type Transformers for General Applications
      b. NEMA TP 1 Guide for Determining Energy Efficiency for Distribution Transformers

1.03 SUBMITTALS
A. Procedure: Section 01 33 00, Submittal Procedures.
B. Product Data: Submit manufacturer’s product data of manufactured materials and equipment including the following.
   1. Outline and support point dimensions of enclosures and accessories
   2. Unit weights
   3. Voltage, kVA and impedance ratings and characteristics
   4. Loss data, efficiency at 25, 50, 75 and 100 percent rated load
   5. Sound level
   6. Tap configuration
   7. Insulation system type and rated temperature rise.
C. Operation and Maintenance Data: Submit in accordance with Section 01 78 23, Operation and Maintenance Data, including the requirements identified above for submittal information.
D. Test Reports: Submit 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 transformers in secure, warm and dry storage facility.
C. Handle transformers using only lifting eyes and brackets provided for that purpose. Protect units against entrance of rain, sleet, or snow if handled in inclement weather.

PART 2 - PRODUCTS

2.01 MATERIALS

A. DRY TYPE TWO-WINDING TRANSFORMERS

1. Dry Type Transformers: NEMA ST 20 and TP 1; factory-assembled, copper windings, \( k=4 \), air cooled dry type transformers; ratings as shown on Contract Drawings.

2. Insulation system and average winding temperature rise for rated kVA as follows:
   a. 1 to 15 kVA: Class 220 insulation, 115 degrees C rise.
   b. 16 to 500 kVA: Class 220 insulation, 115 degrees C rise.
   c. 501 to 2000 kVA: Class 220 insulation, 80 degrees C rise.

3. Load Ratings and Transformer Cooling: Load ratings, unless noted otherwise, are assumed to be AA (air convection cooling). For transformers larger than 500 kVA, provide mounting hardware and internal thermostats appropriate for future installation of external fans. Provisions shall be capable of increasing the transformer full-load rating by 50 percent.

4. Winding Taps
   a. Transformers Less than 15 kVA: Two 5 percent, full-capacity taps below rated voltage on primary winding.
   b. Transformers 15 kVA and larger: NEMA ST 20.

5. Sound Levels: NEMA ST 20

6. Basic Impulse Level.
   a. Low-voltage Dry-Type Transformers: 10 kV.

7. Ground core and coil assembly to enclosure by means of a visible, flexible copper grounding strap.

8. Mounting: Transformers 75 kVA and less shall be suitable for wall, floor, or trapeze mounting; transformers larger than 75 kVA shall be suitable for floor or trapeze mounting.

9. Coil Conductors: Continuous windings with terminations brazed or welded.

10. Enclosure: NEMA ST 20; Type 1, drip-proof.

11. Isolate core and coil from enclosure using vibration-absorbing mounts.

12. Nameplate: Include transformer connection data.
PART 3 - EXECUTION

3.01 INSTALLATION

A. Set transformers plumb and level.

B. Use flexible conduit, 2-foot minimum length, for connections to transformer case. Make conduit connections to side panel of enclosure.

C. Mount transformers on vibration isolating pads suitable for isolating the transformer noise from the structure.

D. Provide restraints for vertical and horizontal seismic motion in accordance with the seismic requirements in Section 26 05 00, Common Work Results for Electrical.

3.02 FIELD QUALITY CONTROL

A. Check for damage and tight connections prior to energizing transformer.

B. Measure primary and secondary voltages and make appropriate tap adjustments.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing low voltage wires and cables, wiring connections, and terminations.
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. 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 Railway Engineering and Maintenance-of-Way Association (AREMA):
   a. AREMA Signal Manual
   a. ASTM B 3 Specification for Soft or Annealed Copper Wire
   b. ASTM D 1000 Test Methods for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications
   c. ASTM D 1518 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 D 5034 Breaking Force and Elongation of Textiles Fabrics (Grab Test)
   a. NFPA 130 Standard for Fixed Guideway Transit Systems
   b. NFPA 70 National Electric Code (NEC)
4. National Electrical Contractors Association (NECA):
   a. NECA 1 Standard Practices for Good Workmanship in Electrical Contracting
5. National Electrical Manufacturers Association (NEMA):
   a. NEMA WC 70 Non-Shielded Power Cable 2000 V or Less
1.03 SUBMITTALS
A. Refer to Section 01 33 00, Submittal Procedures.
B. Submittal Requirements: 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 V wire and 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.

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 VOLT SINGLE CONDUCTOR CABLE
   1. Conductor Material: ICEA stranded or solid copper meeting requirements of ASTM B 3, soft drawn.
   2. Conductor Type:
      b. Size 10 AWG and Larger: Class B stranded.
      c. Size 14 to 1/0 AWG: Type XHHW-2, cross-linked polyethylene insulated in accordance with NEMA WC 70.
d. Size 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: Ensure that power cable for emergency fans and related equipment; emergency lighting and exit sign cables; and all circuits eminating from a UPS fed panel including the feeders from the UPS to that panel, meet the criteria of NFPA 130. The cable shall have a minimum one hour fire resistive rating in accordance with UL 2196. This requirement also applies to the main feeders eminating from the main switchgear and terminating in panels that feed the above listed equipment.

5. All conductors in exposed or surface mounted raceway in air plenums shall be listed fire-resistive cables in accordance with UL 2196.

6. 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 4/0 AWG, as indicated.

c. Insulation: As specified above for single conductor cable.

d. Overall Covering: Cable shall be jacketed over the insulation.

e. Multiple conductor for control wire shall be minimum of 14 AWG stranded copper.

f. Insulation Rating: 600 V.

2. Multi-conductor cable shall be made 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. The jacket used shall 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 16 AWG or larger as indicated.

E. BARE CONDUCTOR

1. Use ASTM B 3, Class B stranded, annealed soft-drawn copper conductor unless otherwise indicated. Size as indicated. Use bare conductor for ground wire only.

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.

2. 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.

3. Footage Marker Tape: Provide cables with a footage marker tape under the jacket or hot-foil footage printing on the jacket.

4. Power Cables: Conform to the following color coding for power cables:

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<th>208Y/120 V</th>
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<td>Phase A</td>
<td>Brown</td>
<td>Black</td>
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<tr>
<td>Phase B</td>
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<tr>
<td>Phase C</td>
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<tr>
<td>Neutral</td>
<td>White</td>
<td>White</td>
</tr>
<tr>
<td>Ground</td>
<td>Green</td>
<td>Green</td>
</tr>
</tbody>
</table>

5. Use solid color insulation or solid color coating for branch circuit phase conductors 10 AWG and smaller and all neutral and equipment ground conductors.

6. Use a background color other than white or green for phase conductors with colored tracers.

7. 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.

8. On-site coloring of ends of conductor may be permitted by the Resident Engineer 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 noninjurious 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 D 3005:
      1) Thickness: 7 mils.
      2) Breaking Strength: 15 pounds per inch.
      3) Elongation: 200 percent.
      4) Dielectric Strength: 10 kV/mil.
      5) Insulation Resistance (Direct method of electrolytic corrosion): 10 MW.
   c. For rubber electrical insulating tape for protective overwrapping 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 kV.
      3) Insulation Resistance (Indirect Method of Electrolytic Corrosion): 10 MW.
   d. For Arcproof tape use flexible, conformable organic fabric, coated one side with a flame-retardant flexible elastomer, self-extinguishing, with the following minimum properties:
      1) Thickness, ASTM D 1000: 55 mils.
      2) Tensile Strength, ASTM D 5034: 50 pounds per inch.
      3) Thermal Conductivity, ASTM D 1518: 0.0478 Btu (h/ft²/F).
      4) Electrical Arc Resistance: Withstand 200 A arc for 40 seconds.
   e. Mark each tape package to indicate shelf-life expiration date.

H. CONDUCTOR BUNDLING STRAPS
   1. Provide conductor bundling straps formed from self-extinguishing nylon having a temperature range of minus 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. 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.

B. 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.

C. Do not bend cables during installation, either permanently or temporarily, to radii less than 12 times the outer diameters, except where conditions make the specified radius impractical and shorter radii are permitted by the manufacturer.

D. Bundle cable and conductors neatly and securely with nylon straps in branch circuit panelboards, cabinets, control boards, switchboards, and motor control centers. Bundle power cables separately from control cables.

E. 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.

F. 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 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 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.

G. 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, the existing locations of cables, cable supports, and grounding shall be modified as required to provide a properly arranged and supported installation.

H. Splices and Terminations:
1. Make wire and cable splices only in outlet, junction or pull boxes, or in equipment cabinets. Splice in multiconductor, medium-voltage 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. Mechanical hand tools, with dies for each conductor size as recommended by the manufacturer, may be used on conductor sizes through #6 AWG.

4. For conductor sizes larger than #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 shall 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.

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 600V 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 05 12 00, Structural Steel Framing.
2. Section 12 93 00, Site Furnishings
3. Section 26 05 25, Wire and Cable.
4. Section 26 08 00, Commissioning of Electrical Systems.
5. Section 32 31 13, Chain Link Fences and Gates;

1.02 REFERENCES

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

   a. ASTM B 3 Specification for Soft or Annealed Copper Wire
   b. ASTM B 187 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

1.03 SUBMITTALS

A. Refer to 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 pigtails for future connections to the grounding system by others. Indicate on drawings the locations of test points to measure grounding resistance.

C. Product Data: Submit manufacturers’ product data of grounding materials and coal-tar epoxy protective coating.
1.04 QUALITY ASSURANCE

A. Qualifications: Provide training for electricians involved in the selection, maintenance and operation of exothermic welding materials and equipment. Ensure resistance testing is 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 B 3, Class B stranded, annealed copper conductor, unless otherwise indicated, size as indicated.

C. Bus Bar: ASTM B 187, 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 Tneme-Tar or approved equal.

PART 3 - EXECUTION

3.01 INSTALLATION

A. 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. Above-ground 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 NEMA 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.

B. 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.

C. Station Electrical System Grounding Electrode:

1. Provide ground ring with multiple ground rods or concrete-encased grounding electrode system. Unless otherwise indicated, conductors of the grounding ring shall be buried 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.

D. Traction Power Substation and Tie Station Grounding Electrode:

1. Provide grounding grid with multiple ground rods or concrete-encased electrode as indicated on Contract Drawings. Unless otherwise indicated, bury conductors of the grounding grid in native fill not less than 36 inches below final grade.

2. 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 No. 6 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 a bare copper equipment-grounding conductor 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, and receptacles. Provide grounding bushings or compression connectors attached with machine screws for bonding.

G. Facility 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 structures, equipment cabinets, handrails, fences, bollards, cable, chain barriers, or 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 metallic objects within 15 feet of the track centerline to individual ground rods. Bond continuous metallic objects, such as fences, at a minimum, every 30 feet. Provide ground rods where necessary for this purpose.

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.


3. Traction Power Substation or Tie Station Grounding Electrode: 5 ohms, maximum.


END OF SECTION
SECTION 26 05 33
RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing electrical raceways including conduit, duct and cable tray, outlet, junction and pull boxes, 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 26, Grounding and Bonding For Electrical Systems.
2. Section 26 05 43, Underground Ducts and Raceways for Electrical Systems.
3. Section 26 05 00, Common Work Results for Electrical

1.02 REFERENCES

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

1. American National Standards Institute (ANSI):
   a. ANSI C80.1 Rigid Steel Conduit - Zinc Coated

   b. ASTM A 153/A 153M 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 FG 1 Fiberglass Cable Tray Systems
   b. NEMA RN 1 Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
   c. NEMA TC 2 Electrical Polyvinyl Chloride (PVC) Tubing and Conduit
   d. NEMA TC 3 PVC Fittings for Use with Rigid PVC Conduit and Tubing
   e. NEMA TC 6 & 8 PBC Plastic Utilities Duct for Underground Installations
f. NEMA TC 14 Reinforced Thermosetting Resin Conduit (RTRC) and Fittings

g. NEMA VE 1 Metallic Cable Tray Systems

h. 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. Procedure: 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 Contract 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 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 may 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. Submit shop drawings showing the exact location and arrangement of conduits, cabinets, and pullboxes installed under this Contract. Submit drawings with ample time to prevent delays in the Work.

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; each length shall bear UL label.

   a. Fittings and Accessories:

      1) Bushings: Nylon-insulated, metallic, grounding type.

      2) Conduit straps, clamps, and clamp backs: Galvanized malleable iron.

2. PVC-Coated GRS Conduit (PVC/GRS): NEMA RN 1, with corrosion resistant internal coating.
a. Shipping: Thread protectors installed on both ends of conduit, with couplings packaged separately.

3. PVC Electrical Conduit and Fittings: NEMA TC 2, EPC-40-PVC; heavy wall, high impact strength, rigid PVC.
   a. Fittings: NEMA TC 3, EPC-40-PVC.

4. Plastic Utilities Duct: NEMA TC 6 & 8, Schedule 20 type EB.

5. Epoxy and Phenolic Fiberglass Conduit and Fittings: NEMA TC 14; standard-wall
   a. Conduit joints and fittings: Tapered or untapered; all of one type.

6. Innerduct
   a. Premanufactured multi-cell raceway assembly:
      1) Four 1-inch inside-diameter, pre-lubricated PVC innerducts pre-installed in 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.

7. 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 liquidtight 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.

8. 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. Two or more channels may be welded together to form horizontal members of greater strength.
   c. Hot-dip galvanized after fabrication in accordance with ASTM A 123/A 123M or ASTM A 153/A 153M, as applicable.
   d. Manufacturer: Unistrut or approved equal.

E. METALLIC CABLE TRAYS

1. Cable Tray: NEMA VE 1, except for modifications indicated.
2. Components: Hot-dip galvanized steel in accordance with ASTM A 123/A 123M, or stainless steel Type 304 or Type 316, as indicated.
3. Dimensions: Use trays with a width of 6 inches minimum and a loading depth of 3 inches minimum. Use trays with an inside nominal depth of 5 inches minimum. Use curved fittings with a 24 inches minimum curve radius, unless otherwise approved by the Resident Engineer.
4. Type: Ladder type or solid bottom type with solid covers, as indicated.
5. Performance Requirements:
a. Verify the cable tray system is capable of supporting a total cable load of 55 pounds per linear foot for cable tray of 30 inches wide or less and 88 pounds per linear foot for cable tray over 30 inches wide on a maximum span of 8 feet including a static concentrated load of 200 pounds as specified below, with a safety factor of two based on the destructive load, regardless of the type of splice plates or type of span, when tested in accordance with load test procedure specified in NEMA VE 1.

b. Ensure that straight sections and fittings don’t permanently deform under a 200-pound static concentrated load applied vertically along a 4-inch length for both of the following conditions:

1) Load applied to center of one tray section having specified cable load and support spacing. Apply load at midpoint between supports over a splice connection.

2) Load applied to one rung of empty tray section having specified support spacing. Locate the load at midpoint between side rails and supports.

6. Cable Tray Supports:

a. Capable of carrying a working load of 100 pounds per linear foot, with a safety factor of 3.0 when loaded in accordance with NEMA VE 1, Section 3, and tested in accordance with NEMA VE 1, Section 4.

b. Manufactured or fabricated in accordance with the cable tray manufacturer’s recommendations.

F. FIBERGLASS CABLE TRAYS

1. Cable Tray: NEMA FG 1, except for modifications indicated.

2. Conform with requirements of metallic cable trays as applicable to plastic systems.


G. 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. Not all junction boxes are shown on the plans. Junction boxes and pull boxes shall be installed as necessary by the contractor to aid in pulling wire, and to be in conformance with the NEC. There shall not be more than 270 degrees of conduit bends between pull points per sound transit criteria. Contractor is to coordinate the location of the junction boxes and pull boxes with other trades to ensure that the boxes will remain accessible after all construction is complete.

3. Provide boxes complete with accessible covers designed for quick removal and suitable for the purpose for which they will be used, except that boxes in which, or on which, no devices or fixtures are to be installed shall be equipped 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. Pedestrian type junction boxes shall be used for applications that require a junction box to be embedded in floor concrete or grade. The junction boxes shall be designed to be mounted in sidewalks and other flat concrete surfaces. The boxes shall have checkered covers and be made to withstand pedestrian traffic. These boxes shall be provided with a flat, neoprene gasket, attached to the cover. This box shall be cast iron with stainless steel cover screws. The finish shall be hot dip galvanized.

6. 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.

7. 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.

8. For exposed installation, use outlet and switch boxes made of cast metal, not smaller than 4 inches square by 2-1/8 inches deep.

9. Provide brackets, supports, hangers, fittings, bonding jumpers, and other installation accessories as required.

10. Provide neoprene gaskets 1/8-inch thick for boxes subjected to weather.

11. Ground each box as specified in Section 26 05 26, Grounding and Bonding For Electrical Systems.

12. Ensure boxes for systems control and communications applications conform to NEMA 250 Type 4 and shall be provided with NEMA Type 4 labels.

13. All junction boxes for use in escalator or elevator pits shall be rated NEMA 12.

H. Cabinets

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. General Requirements

1. Install electrical raceway, boxes and accessories in locations as indicated, in accordance with NFPA 70 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.

B. Conduit and Duct Type Requirements

1. Above grade exterior or potentially-wet areas: GRS or fiberglass conduit.

2. Below grade interior spaces (tunnels, shafts, and tunnel passenger stations): PVC/GRS or fiberglass 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 (see Section 26 05 43, Underground Ducts and Raceways for Electrical Systems).

5. PVC electrical conduit may only be installed where 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. Running thread shall not be used.

C. 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.

D. 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 Bend Radius Within Structures: In accordance with National Electrical Code Chap.9, Table 2

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. PVC Conduit Bending Restrictions
   a. Hot bend bends with radii less than 100 feet using a heater recommended by the conduit manufacturer. Bends with radius 100 feet or larger may be cold bent.
   b. Do not bend PVC conduit used in ductbanks with a radius less than 6 feet.

5. EB Duct Bending Restrictions
   a. Do not hot bend Type EB duct.
   b. Type EB duct may be cold bent for slight offsets or changes in direction. Do not cold bend EB duct for radii less than 120 feet.
E. 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 do 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.

F. 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 further requirements.
G. 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.

H. 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.
   b. Do not install boxes above suspended ceilings, except where the ceiling is of the removable type or where definite provisions are made for access to each box.

I. CABLE TRAYS

1. Install cable trays as indicated using approved fittings and adequately supporting the complete system.

2. Provide anti-sway brackets on horizontal tray assemblies in accordance with approved Seismic Bracing and Anchorage Plan (see Section 26 05 00, Common Work Results for Electrical).

3. Connect each isolated cable tray system or the entire tray system to the building equipment grounding system with a bare copper conductor in accordance with National Electrical Code.
4. Provide expansion/deflection fittings in cable tray installations where they cross structure expansion joints and to accommodate differential expansion between cable tray and structure. Bond metallic cable trays across expansion/deflection fittings.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for underground electrical conduits, ductbanks, and underground utility 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 03 05 15, Portland Cement Concrete.
2. Section 03 11 00, Concrete Formwork.
3. Section 03 20 00, Concrete Reinforcing.
4. Section 03 30 00, Cast-in-Place Concrete.
5. Section 26 05 33, Raceways and Boxes for Electrical Systems.
6. Section 31 23 33, Trenching and Backfilling.

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

   a. ASTM C33 Specification for Concrete Aggregates

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

B. Shop Drawings:

1. Submit shop drawings for fabrication and installation of precast concrete structures, cast-in-place concrete structures, and concrete-encased underground ductwork, including the following:
   a. Excavation and shoring plans with required structural calculations;
   b. Cast-in-place and precast detailed steel reinforcement drawings;
   c. Details of reinforcing steel used to tie ductbank to rigid underground structures it enters;
   d. Cast-in-place and precast manufacturer's concrete mix designs for structures and colored concrete as indicated;
e. Dimensions and details of structure; and
f. Vault covers, including inscription.

2. Shop drawing information may be combined on a single drawing if clarity is not thereby impaired.

3. Submit shop drawings which fully demonstrate that the work to be performed and the materials to be provided comply with the provisions of these Specifications.

C. Submit a list of five major projects for which similar products have been supplied, which have been in satisfactory use or operation for the past 5 years.

D. Product Data. Submit the following:

1. Complete materials list of items proposed to be provided under this Section.

2. Manufacturers' specifications and other data required to demonstrate compliance with these Specifications.

3. Catalog cuts for the following products:

   a. Raceways.

   b. Ductbank tie-downs.

   c. Underground duct system including manholes, pull boxes, handholes, cable junction boxes, and termination boxes.

   d. Manhole, pull box, and handhole covers and frames.

   e. Related miscellaneous hardware and metal items for cable trenches and wireways.

   f. Trench and wireway covers including composition of FRP materials, divider partition panels, method of joining sections, expansion joint mounting, and support details.


1.04 QUALITY ASSURANCE

A. Qualification of Manufacturers:

1. Select manufacturers of the products specified for work under this Section who are in the business of manufacturing similar products and are able to provide a history of successful production of the specified products.

2. Inspection: Ensure completed facilities are approved by the Resident Engineer before installation of cable and equipment. Perform corrective work at no additional cost to Sound Transit.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Raceways
1. Conduit and duct: In accordance with Section 26 05 33, Raceways and Boxes for Electrical Systems.

B. Precast concrete electrical boxes, pullboxes, and vaults
1. Reinforce concrete in a manner which is regularly provided in standard products of the manufacturer.
2. Standard manufactured structures which meet project requirements will be acceptable.
3. Provide concrete inserts for mounting cable support brackets as indicated.
4. Provide pullbox covers with two lifting eyes and two holddown bolts.

C. Cast-In-Place Concrete for Ductbank Encasements, Manholes, Pull Boxes, and Vaults
1. Concrete: 3000 psi with 4-inch slump in accordance with Section 03 05 15, Portland Cement Concrete.
2. Red concrete: As specified in Section 03 05 15, Portland Cement Concrete, using 100 pounds of iron oxide for 8 cubic yards of concrete.
3. Construct formwork and place concrete in conformance with applicable requirements of Section 03 11 00, Concrete Formwork, and Section 03 30 00, Cast-in-Place Concrete.
4. Install reinforcing steel, as indicated, in conformance with applicable requirements of Section 03 20 00, Concrete Reinforcing.
5. Frames, Covers, Gratings, Steps and Sumps: Provide as indicated and in accordance with Systems Standard Drawings and Contract Drawings.
6. Cover Identification: Provide covers with embossed or engraved identification as indicated and in accordance with Systems Standard Drawings.

D. Sand
1. Clean, graded, washed, passing a No. 4 U.S. sieve, and conforming generally to ASTM C33 for fine aggregate.

E. Warning tape
1. Heavy gage, yellow, plastic for direct burial, material resistant to corrosive soil, 6-inch minimum width, minimum 4 mils thick.
2. Printed with warning that an electrical circuit is located beneath the tape.

F. Ductbank tie-down
1. Non-metallic rod or stake with sufficient friction to prevent ducts from pulling rod out of ground and “floating” when concrete is placed.
PART 3 - EXECUTION

3.01 PREPARATION

A. Before beginning construction or installation of a section of underground conduit or ductwork, verify that the site is in suitable condition for installing conduit or ductwork as indicated.

3.02 EXCAVATION, TRENCHING AND BACKFILLING

A. Perform excavation, bedding, and backfilling for underground conduits and structures in accordance with Section 31 23 33, Trenching and Backfilling.

3.03 CONSTRUCTION

A. Ductbanks

1. Group individual conduits together to form a ductbank in conformance with the requirements specified herein.

2. Inspect ducts and couplings to ensure that only clean and undamaged pieces are incorporated in the work.

3. Install ducts, joints, and space separators according to manufacturer's printed instructions and recommendations.

4. Do not use spacers or space separators which transmit any vertical load to the conduit.

5. Install ductbanks or conduits with a minimum slope of 3 inches to each 100 feet away from buildings and towards manholes, pull boxes, and handholes.

6. Terminate conduits and ducts in end-bells in vaults.

7. Where ductbank enters rigid underground structures, provide reinforcing steel to tie the ductbank to the structure.

8. Construct the concrete-encased ductbank with 3-inch minimum cover on all sides.

9. Protection: when installation of conduits and ducts is temporarily suspended or terminated, close ends of ducts with caps or plugs fitted to prevent entry of water or debris. Use caps or plugs designed for that purpose by the conduit manufacturer.

10. Mandrelling: As each section of a duct line is completed between manholes, handholes, or pullboxes, use testing mandrel not more than 1/4 inch less than the size of the conduit to drawn through each conduit, after which draw a brush with stiff bristles through until the conduit is clear of particles of earth, sand, or gravel. Install conduit caps or plugs immediately thereafter. Notify the Resident Engineer prior to mandrelling any conduit and submit a written report providing a conduit identification number, size, material, location, the type and size of mandrel used, and indicate whether the conduit is tagged. Verify the report also indicate the acceptance date and initials of the accepting Sound Transit inspector and be verified by the Contractor's foreman and Sound Transit inspector.
11. Install 1/8 inch or larger diameter polypropylene pulling cord in ducts including innerducts. Fasten each cord to pull iron anchorage in pull box, manhole, or vault with 2 feet minimum slack.

B. Innerduct System:

1. Provide three raceways within the Signal/Communications raceways with four 1.25-inch innerducts each. Unless noted otherwise on the Contract Drawings, provide innerduct in the three right-most ducts (facing toward increasing stationing) for segments south of International District Station.

2. Install innerduct in accordance with manufacturer's installation instructions and recommendations.

3. Innerducts may be installed as part of a multi-cell raceway assembly or separately after installation of the ductbank is complete.

4. If installed separately, avoid excessive tension and deformation of the innerduct during placement in communications conduits. Replace damaged or necked down innerduct.

5. Couple corresponding innerducts together within intermediate vaults.

C. Precast Concrete Structures

1. Install precast electrical boxes, pullboxes, handholes, manholes, and vaults as indicated.

2. Place boxes on 4 inches of compacted sand bedding.

3. Place manholes on 6 inches of compacted aggregate base.

4. Seal unused openings with cement mortar.

D. Cast-In-Place Concrete Structures

1. Ensure the location of each pull box, manhole, and vault are approved by Resident Engineer before construction of structure is started.

2. Construct the top, walls, and bottom of reinforced concrete. Construct the walls and bottom of monolithic concrete construction.

3. Place concrete for pull boxes, manholes, and vaults on well-compacted soil with a minimum of 6 inches of aggregate base.

4. Provide gray cast iron frames and covers. Provide a machine-finished cover seat to ensure a matching joint between the frame and cover.

5. Where duct lines enter pull boxes, manholes, and vaults, the sections of duct may be either cast in the concrete or may enter through a square or rectangular opening of suitable dimensions provided in the utility structure.
6. Provide a cable-pulling iron anchorage in the wall opposite each ductbank entrance.

7. Install vault or pullbox covers flush with sidewalks or curbs.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for providing 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: Identification of conduit by system.

1.02 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Submit manufacturer’s product data for mounting adhesive.
C. Submit 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. Degrease and clean surfaces to receive nameplates.
B. Install nameplates parallel to equipment lines.
C. Secure nameplates to equipment fronts using screws or adhesive. Secure nameplate to inside face of recessed panelboard or cabinet doors in finished locations.

3.02 CONSTRUCTION

A. IDENTIFICATION SCHEDULE

1. 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, a cable tag may be used. Attach tag securely to cable with plastic cable tie.

   a. Power and Lighting Circuits: Identify with branch circuit or feeder number.

   b. Control Wiring: Identify with control wire number as indicated on the Contract Drawings.

2. Provide nameplates of minimum letter height as scheduled below.

   a. Panelboards, Switchboards, Uninterruptible Power Supplies, Motor Control Centers, Lighting Controllers: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating and source.

   b. Disconnect Switches: 3/8 inch, identify equipment designation; 1/4 inch, identify voltage rating, source, and load served.


   d. Motor Starters in Motor Control Centers: 1/4 inch; identify circuit and load served, including location.

   e. Individual Circuit Breakers, Enclosed Switches, and Motor Starters: 1/4 inch; identify load served.

   f. Transformers: 3/8 inch; identify equipment designation. 1/4 inch; identify primary and secondary voltages, primary source, and secondary load and location.

   g. Devices: 1/4 inch; identify device.

      1) Dimmers

      2) Control devices

      3) Pushbutton stations

B. CONDUIT COLOR CODING

1. Coordinate color of paint with Section 09 90 00, Painting and Coating, to identify conduit by system.

2. Medium-Voltage Distribution System: Orange

3. Low-voltage Distribution System: Unpainted or black
4. Fire Alarm System: Red

END OF SECTION
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SECTION 26 08 00
COMMISSIONING OF ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes conductor insulation resistance testing, medium-voltage dielectric testing, and grounding electrode system testing.

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.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Electrical Megohmmeter for Insulation Testing:
   1. 1000 V 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.

B. High-Potential Test Set:
   1. Portable high-potential dc test set, 0 to 130 kVdc, 10 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. 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, light standards, metal fencing, and other bonded equipment for continuity to the ground system.

C. Low- and Medium-Voltage Wire and Cable Insulation Resistance Tests:
   1. Measure insulation resistance with a 1000 V dc megohmmeter. For medium-voltage cable, insulation resistance measurement may be made with the dc high-potential test set if equipment is suitable for that purpose.
   2. Measure insulation resistance between conductor and ground.
   3. Test cables after splices and terminations are complete. Do not connect any equipment to the cable system during tests.

D. Medium-Voltage Cable Insulation Tests:
   1. Test medium-voltage cables using a dc high-potential test set.
   2. Test and safety procedures shall conform to recommendations of the cable manufacturer and test equipment manufacturer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for the furnishing, installing, and testing, including all wire, cable and mounting of the Double ended unit substation. The double ended unit substation includes:

1. Medium voltage cable connection to transformer from top.
2. Medium voltage dry-type transformer.
3. Switchgear section, main – tie – main arrangement between two close coupled transformers

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 25, Wire and Cable.
2. Section 26 05 26, Grounding and Bonding for Electrical Systems.
4. 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/NETA 7.2.1 Maintenance Testing Specifications for Dry-Type Transformers: Air-Cooled, 600 Volts and Below - Small (167 kV Single-Phase, 500 kVA Three-Phase, and Smaller) and Air-Cooled, All Above 600 Volts and 600 Volts and Below - Large (Greater than 167 kV Single-Phase and 500 kVA Three-Phase)
   b. ANSI/IEEE C37.13.1 Definite Purpose Switching Devices for Use in Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
   c. ANSI C37.16 Low Voltage Power Circuit Breakers and AC Power Circuit Protectors
   d. ANSI/IEEE C37.35 Guide for the Application, Installation, Operation, and Maintenance of High-Voltage Air Disconnecting and Interrupter Switches
   e. ANSI C37.17 Trip Devices for AC and General Purpose DC Low-Voltage Power Circuit Breakers
   f. ANSI/IEEE C37.30 Standard Requirements for High Voltage Switches
g. ANSI C37.50 Switchgear - Low-Voltage AC Power Circuit Breakers Used in Enclosures - Test Procedures
h. ANSI C37.121 Switchgear - Unit Substations - Requirements
i. ANSI/IEEE C57.12.91 Standard Test Code for Dry-Type Distribution and Power Transformers
j. ANSI/IEEE C57.13 Standard Requirements for Instrument Transformers
k. ANSI/IEEE C57.12.01 Standard General Requirements for Dry-Type Distribution and Power Transformers Including Those with Solid-Cast and/or Resin Encapsulated Windings
l. ANSI C57.12.50 Distribution Transformers 1 to 500 kVA, Single-Phase; and 15 to 500 kVA, Three-Phase with High-Voltage 601-34 500 Volts, Low Voltage 120-600 Volt, Ventilated Dry-Type
m. ANSI C57.12.51 Dry-Type Power Transformers 501 kVA and Larger, Three-Phase with High-Voltage 601 to 34 500 Volts, Low-Voltage 208Y/120 to 4160 Volts, Requirements for Ventilated
n. ANSI/IEEE 344 Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations

   a. ASTM B117 Standard Practice for Operating Salt Spray (Fog) Apparatus
   b. ASTM D522 Standard Test Methods for Mandrel Bend Test of Attached Organic Coatings
   d. ASTM D3363 Standard Test Method for Film Hardness by Pencil Test

3. Institute of Electrical and Electronics Engineers (IEEE):
   a. IEEE C57.12.91 Standard Test Code for Dry-Type Distribution and Power Transformers

1.03 SUBMITTALS:

A. Working Drawings: Submit working drawings including a coordinated unit substation set of plans, elevations, and details showing all section alignments and connections between sections.

B. Coordination Drawing: Submit unit substation dimensioned plans, elevations, sections, including required clearances and service space around equipment for each substation section. Ensure that the drawings of switchgear front and plan layout and relationships between components and adjacent structural and mechanical elements. Also show on the drawings, support locations, type of support, and weight on each support. Include shipping sections to ensure they will not pose any problem of bring in and out of the electrical room thru equipment hatch shown in the floor plan of the electrical room.

C. Manufacturer Seismic Qualification Certification: Submit certification that unit substation sections, accessories, and components will withstand seismic forces as defined in the
building code applicable to the site and of Contract Specifications. Include the following within submittal:

1. Basis for certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation. The term "withstand" means the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.

2. Dimensioned outline drawings of equipment unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Submit a detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. Design Calculations: Submit design calculations signed and sealed by a registered professional engineer in the State of Washington. Include within the submittal calculations for requirement for seismic anchorage restraints.

E. Equipment Pads: Provide coordinated equipment pad layout and attachment detail working drawings.

F. Submit working drawings and data sheets on all unit substation sections and components including dimensions and manufacturer’s technical data on features, performance, electrical characteristics, ratings, and finishes.

G. Include the following on incoming line sections submittal:

1. Working drawings:
   a. Outline and section plans showing components and arrangement.
   b. Incoming primary cable terminations entering from above or below.
   c. Primary termination details of medium voltage cable to transformer.
   d. Transition bus configuration, current, and voltage ratings.
   e. Short-circuit current rating.
   f. Alignment and connection details.
   g. Coordinated transformer primary bushing connections on line side.

2. Factory test reports

H. Medium voltage transformer: Include the following in the submittal:

1. Product data: Include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features and performance for each type and size of transformer indicated.

2. Working drawings:
   a. Outline and section plans showing components and arrangement.
   b. Primary and secondary bus termination details
   c. Anchorage details.
d. Diagram power and alarm/signal wiring.

3. Factory test reports.

I. Double ended switchgear section: Include the following in the submittal:

1. Product data: Include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features, tools list and performance for each type and size of switchgear indicated.

2. Working drawings:
   a. Outline and section plans showing components and arrangement.
   b. Primary and secondary bus termination details.
   c. Bus configuration, current, and voltage ratings.
   d. Short-circuit current rating of switchgear and overcurrent protective devices.
   e. Switchgear alignment and connection details.
   f. Coordinated transformer secondary bus connections on load side.
   g. Descriptive documentation of optional barriers specified for electrical insulation and isolation.
   h. Mimic-bus diagram.
   i. Features, characteristic, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
   j. Wiring diagrams including power, alarm signal, and control wiring.
   k. Load transfer scheme between main circuit breakers and tie circuit breaker during a source outage.

3. Factory test reports.

J. Include the following in the field quality control for unit substation sections and components submittal:

1. Field test data:
   a. Test procedures used.
   b. Test results that comply with requirements.
   c. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

2. Field service reports.
   a. Test procedures used.
   b. Equipment and components inspected.
   c. Inspection items.
d. Inspection results and remedies taken.

3. Operation and maintenance manuals for unit substation sections and components.

4. Warranty for unit substation and components.

1.04 QUALITY ASSURANCE

A. Manufacturer's Certification:
Ensure a qualified factory-trained manufacturer's representative(s) certifies, in writing, that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations. Provide three copies of the manufacturer's representative's certification.

1.05 PROJECT CONDITIONS

A. Conform service conditions to IEEE C37.121, usual service conditions except for the following:

1. Exposure to seismic shock or to abnormal vibration, shock, or tilting.

2. Unusual space limitations:
   a. Product selection for restricted space: Indicate on Contract Plans all dimensions for double ended unit substation sections, including clearances between switchgear and adjacent surfaces and other items. Select products to conform to the maximum dimensions as indicated.

1.06 MAINTENANCE

A. Provide ten copies of the equipment operation and maintenance manuals. Operation and maintenance manuals in conformance with "01-78-23 Operation and Maintenance Data" of these special provisions.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Verify the manufacturer is ISO 9000, 9001 or 9002 certified for the double ended unit substation equipment specified herein.

B. Obtain all double ended unit substations and associated components through one manufacturing source. The source manufacturer is responsible for the complete unit substation design; and, is, at a minimum, the manufacturer of the outgoing switchgear sections:

1. Conform all working drawings to industry standard (IEEE) drafting and nomenclature standards.

2. Ensure all working Condtact Drawings are reviewed and signed by qualified staff engineer.

3. For the manufacturer of the incoming line section and the outgoing switchgear section use a major medium voltage switchgear manufacturer and have a qualified in-house engineering staff for the switchgear assembly and controls system design.
2.02 MANUFACTURED UNITS

A. Proposed products with dimensions larger than shown on contract drawings are not acceptable. Ensure size of the double ended unit substations meet code requirements for the work space and maintenance access clearances.

B. The double ended unit substations: Ensure all substations are of the single unit type complete from the incoming line terminals to the outgoing secondary feeder breakers terminals.

C. For incoming line section use an indoor type, designed in accordance with ANSI C37.30, ANSI C37.35, NEMA SG6 and NEC 2005 including:
   1. Three approved terminals for incoming cables of adequate capacity entering from above or below. Ensure the enclosure is large enough to accommodate built-up tape stress cones.

D. Medium Voltage Transformers
   1. Provide dry-type, 2-winding transformers in conformance with NEMA ST20, ANSI C57.12.50 or ANSI C57.12.51 IEEE C57.12.01. Ensure transformer is UL 1562 listed and labeled.
      a. Use a transformer designed for indoor, ventilated use and vacuum-pressure impregnated, with insulation system rated at 220 degrees C with a 150 degrees C average winding temperature rise above a maximum ambient temperature of 40 degrees C.
   2. Ensure the transformer is rated 3000 kVA base (AA), 26,000-480Y/277V, 3-phase, 60 Hz.
   3. Use a transformer percent impedance of 5.75 or lower.
   4. Conform insulation materials to IEEE C57.12.01, and rated at 220 degrees C.
   5. High-voltage basic impulse level: 150 kV peak, low-voltage basic impulse level: 10 kV peak
   6. Full-capacity voltage taps: four nominal 2.5 percent taps, 2 above and 2 below rated primary voltage.
   7. Cooling system:
      a. 150 degrees C: Class AA, self-cooled.
      b. Provisions with Class FA, force-air cooling system.
      c. Install fans with this unit. Fans must be installed with this unit to provide sufficient capacity during emergency loading.
   8. Do not exceed sound levels listed in NEMA TR 1.
   9. Outgoing switchgear bus connections:
      a. Make all equipment chamber secondary connections bussed with transition bus section or bus transition internal to transformer enclosure, with copper bus connection pattern to match switchgear. Provide flex bus connections to switchgear buses.
10. **Factory tests:** Perform design and routine tests in conformance to standards specified for components. Conduct transformer tests in conformance to ANSI C57.12.50 ANSI C57.12.51 IEEE C57.12.91, as applicable.

11. Perform the following factory-certified tests on each transformer:
   a. Resistance measurements of all windings on rated-voltage connection and on tap extreme connections.
   b. Ratios on rated-voltage connection and on tap extreme connections.
   c. Polarity and phase relation on rated-voltage connection.
   d. No-load loss at rated voltage on rated-voltage connection.
   e. Excitation current at rated voltage on rated-voltage connection.
   f. Impedance and load loss at rated current on rated-voltage connection and on tap extreme connections.
   g. Applied potential.
   h. Induced potential.
   i. Temperature test: Performed test at lowest kilovolt-ampere Class AA rating. Temperature test is not required if record of temperature test on an essentially duplicate unit is available. Submit test report to the Engineer for review and approval.

12. **Transformer protection and control devices:**
   a. Protection and indicating devices shall be provided as shown on the contract drawings and as specified herein.
   b. Winding temperature gauges shall be provided and mounted for viewing from outside of the transformer enclosure through viewing window. The temperature gauge shall be provided with two stage contacts. First stage contact shall be for remote annunciation and second stage for tripping the associated circuit breaker as indicated on the contract drawings.
   
   1) The pickup point of the first stage shall be adjustable and factory set so that upon a designated temperature increase the device initiates an alarm.
   
   2) Further temperature increase, the device shall initiate the tripping of the associated circuit breaker.

**E. Switchgear Section**

1. **Front-and rear-accessible switchgear:** Front or rear aligned as noted, with features as follows:
   a. Service rated and as indicated on the Contract Drawings.
   b. Main – tie- main and feeder breakers: Drawout mounted.

2. Nominal system voltage: 480Y/277 V.
3. **Main-bus continuous current:** As shown on plans.

4. **Fabricate and test switchgear in conformance to IEEE 344 to withstand seismic force defined in IBC and as indicated on structural drawings.**

**F. Enclosure:** Steel, NEMA 12.

1. **Enclosure finish for indoor units:** Factory-applied finish in manufacturer's standard gray finish over a rust-inhibiting primer on treated metal surface.

2. **Barrier:** Between adjacent sections.

3. **Insulation and isolation for main bus of main section and main and vertical buses of feeder sections.**

4. **Bus transition sections:** Matched and aligned with basic switchgear.

5. **Removable, hinged rear doors and compartment covers:** Secured by captive thumb screws, for access to rear interior of switchgear.

6. **Hinged front panels:** Allow access to circuit breaker, metering, accessory, and blank compartments.

7. **Buses and connections:** Three phase, three wire, unless otherwise indicated:
   a. **Phase bus material:** Hard-drawn copper of 98 percent conductivity with feeder circuit-breaker line connections. Use copper for feeder circuit-breaker line connections.
   b. **Load terminals:** Insulated, rigidly braced, silver-plated, copper runback bus extensions equipped with pressure connectors for outgoing circuit conductors. Provide load terminals for future circuit-breaker positions at full ampere rating of circuit-breaker position.
   c. **Ground bus:** 1/4-inch by 2-inch minimum-size, hard-drawn copper of 98 percent conductivity, equipped with pressure connectors for feeder and branch-circuit ground conductors.
   d. **Contact surfaces of buses:** Silver plated.
   e. **Main phase buses and equipment ground buses:** Uniform capacity of entire length of switchgear's main and distribution sections. Provide for future extensions from both ends.
   f. **Isolation barrier access provisions:** Permit checking of bus-bolt tightness.

**G. Future devices:** Equip compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of circuit-breaker compartment.

**H. Bus-bar insulation:** Factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating: 105 degrees C.

**I. Main and Tie Circuit Breakers.**

1. **Description:** Comply with IEEE C37.13.1.
2. Comply with NEMA standard ICS10-1193- AC Automatic Transfer Switches

3. Ratings: As indicated for continuous, interrupting, and short-time current ratings for each circuit breaker; voltage and frequency ratings same as switchgear.

4. Operating mechanism: Mechanically and electrically trip-free, store-energy operating mechanism with the following features:
   a. Normal closing speed: Independent of both control and operator.
   b. Slow closing speed: Optional with operator for inspection and adjustment.
   c. Store-energy mechanism: Electrically charged, with optional manual charging.
   d. Operation counter.

5. Trip devices: Solid-state, overcurrent trip-device system including one or two current transformers or sensors per phase, a release mechanism, and the following features:
   a. Functions: Long-time-delay, short-time-delay, and instantaneous-trip functions, independent of each other in both action and adjustment.
   b. Field-adjustable, time-current characteristics.
   c. Current adjustability: Dial settings and rating plugs on trip units or sensors on circuit breakers, or a combination of these methods.
   d. Three bands, minimum, for long-time- and short-time-delay functions; marked “minimum,” “intermediate,” and “maximum.”
   f. Pickup points: Five minimum with “off”, for instantaneous-trip functions.
   g. Ground-fault protection with at least three short-time-delay settings and three trip-time-delay bands; adjustable current pickup. Arrange to provide protection for three-wire circuit or system where shown on the Contract Drawings.
   h. Trip indication: Labeled, battery-powered lights or mechanical targets on trip device to indicate type of fault.

6. Use Auxiliary contacts for interlocking or remote indication of circuit-breaker position, with spare auxiliary switches and other auxiliary switches required for normal circuit-breaker operation. Provide quantity as indicated. Include with each two Type "a" and two Type "b" stages (contacts) wire through secondary disconnect devices to a terminal block in stationary housing.

7. Drawout features includes a circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in connected, test and disconnected positions and includes the following features:
a. Interlocks: Prevent movement of circuit breaker to or from connected position when it is closed, and prevent closure of circuit breaker unless it is in connected, test or disconnected position.

b. Circuit-breaker positioning: An open circuit breaker may be racked to or from connected, test, and disconnected position only with the associated compartment door closed unless live parts are covered by a full dead-front shield. An open circuit breaker may be manually withdrawn to a position for removal from the structure with the door open. Status for connection devices for different positions includes the following:

1) Test position: Primary disconnect devices disengaged and secondary disconnect devices and ground contact engaged.

2) Disconnected position: Primary and secondary devices and ground contact disengaged.

8. Arc chutes: Readily removable from associated circuit breaker when it is in disconnected position, and arranged to permit inspection of contacts without removing circuit breaker from switchgear.

9. Padlocking provisions: For installing at least three padlocks on each circuit breaker to secure its enclosure and prevent movement of drawout mechanism.

10. Electric close button: One for each electrically operated circuit breaker.

11. LED indicating lights: To indicate circuit breaker is open or closed, for main circuit breaker interlocked with external devices.

12. Conform instrument transformers to NEMA EI 21.1, IEEE C57.13, and include following:

a. Potential transformers: Secondary voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.

b. Current transformers: Use ratios as indicated, with accuracy class and burden suitable for connected relays, meters, and instruments.

c. Control-power transformers: Dry type, mounted in separate compartments for units larger than 3 kVA.

d. Provide 2-percent accuracy, 3-phase, 4-20 mA current transducer for secondary main bus, with output wired to field terminal block.

12. Provide electrical interlock between Main-Tie-Main breakers such that only two breakers can be closed at one time. Tie breaker can be closed only if one of the main is open.

J. Feeder Circuit Breakers

1. Comply circuit breakers with the requirements of IEEE C37.13.1, ANSI C37.16, ANSI C37.17, ANSI C37.50, UL 1066, NEMA SG3. For all breakers use three-pole, 100 percent rated.

a. Ensure circuit beaker element have Connected, Test, and Disconnected position indicators, Spring Charge/Discharged indicators, and circuit breaker Open or Closed and Ready-to-Close indicators all of which are visible to the operator with the compartment door closed. Make it
possible to rack the circuit breaker element from the connected to the disconnected position with the compartment door closed.

b. Provide interlocks to prevent racking the circuit breaker unless the breaker is open.

2. Rating: Use continuous interrupting and ratings as indicated. Use circuit breaker of 600-volt class.

3. Operating Mechanism: Mechanically and electrically trip-free, store-energy operating mechanism with the following features:
   a. Normal Closing Speed: Independent of both control and operator.
   b. Electrical operator, field installable with manual charging.
   c. Operation counter.

4. Ensure each low voltage power circuit breaker is equipped with self-powered, microprocessor-based trip-device to sense overload and short circuit conditions. Ensure the device measures true RMS current and the tripping system includes sensors on each phase, a release mechanism, and the following features:
   a. Field Installable & Interchangeable so that any trip unit can be used with any frame size circuit breaker. And can be upgraded for future expansion in functionality, such as communication.
   b. Functions: Provide long time, short time and extended instantaneous protection function to allow the breaker to be applied at the withstand rating of the breaker. Ensure each breaker has an adjustable pick-up setting. In addition, ensure long time and short time bands each have adjustable time delay. Include a switchable \( I^2t \) ramp for short time function.
   c. Make a software program free of charge to support system co-ordination. The software will allow time current curves to be generated for the chosen settings.
   d. Use individual LED's to indicate an overcurrent, short circuit or ground fault trip condition. Maintain the data for a minimum of 48 hours without the need for a separate battery.
   e. Allow time-current characteristics to be field adjustable locally.
   f. Current Adjustability: Dial settings and rating plugs on trip units.
   g. Pickup Points: 10 Long Time Settings.
   h. Field Installable Ground-Fault protection with at least three time-delay bands; adjustable current pickup and an \( I^2t \) ramp. Arrange to provide protection for three-wire service.
   i. Field installable zone selective interlocking: Connections will be made between main and feeder circuit breakers to ensure that the circuit breaker closest to the fault trips for short time and ground fault conditions.
   j. Make A LCD display available to simplify settings & viewing data locally.
5. Make mechanism operated cell switch to be operated by the circuit breaker operating mechanism.

6. Make terminal Block Connections, front mounted and with ring tongue terminal.

7. Padlocking provisions for installing at least three padlocks on each circuit breaker to prevent movement of the draw-out mechanism.

8. Built in operating handle complete with handle and integral to breaker. Ensure no external tools are required to rack the breaker.

9. Provide control switch for each electrically operated circuit breaker. Provide each control switch with red (closed) and green (open) status indicating lights mounted on the head front panel. Provide a minimum of two normally closed and two normally open auxiliary controls for remote position indication and equipment control unit comes complete with a shunt trip relay.

10. Make undervoltage trip adjustable time-delay.

11. Lugs: Compression style, suitable for number, size, trip ratings, and conductor material.

12. Control circuits: 120 V, supplied through secondary disconnecting devices from control-power transformer.

13. Control-power fuses: Fuses for protection of control circuits.

14. Control wiring: Factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

K. Accessory components and features

1. Furnish tools and miscellaneous items required for circuit-breaker and switchgear test, inspection, maintenance, and operation.
   a. Racking handle to manually move circuit breaker between connected and disconnected positions.
   b. Portable test set for testing all functions of circuit-breaker, solid-state trip devices without removal from switchgear.


3. Furnish accessory set including tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.

4. Each main feeder shall be monitored with a metering device that monitors the following: local display of 3-phase voltage, current, and frequency; system and per-phase power including watthours, varhours, and VA-hours; system demand including watt demand, VA demand, and var demand; apparent and displacement power factor; and recorded minimums and maximums of these values. The monitored parameters for voltage shall be L-L and L-N true rms measurement, and for amps it shall be provided for each phase. The meter shall be installable on the face of the switchgear and shall be integral with the equipment. The meter shall have interface capability to a computer network for data collection, storage, and/or printout.
L. Factory test:

Perform standard factory tests on the equipment under this section. Conform all tests to ANSI and NEMA standards. Ensure the manufacturer provides 3 certified copies of factory test reports.

M. Factory finish:

Prior to assembly, thoroughly clean and phosphatize all enclosing steel. Electrostatically apply a powder coating, then fused on by baking in an oven. Apply coating to have a thickness of not less than 1.5 mils. Ensure the finish has the following properties:

1. Impact resistance: ASTM D2794: 60 direct/60 indirect
2. Pencil hardness: ASTM D3363: H
4. Salt spray: ASTM B117: 600 hours
5. Color: ANSI 61: gray

N. Identification

1. Substation nameplates: Label substation incoming line section, transformer section and outgoing switchgear section compartments to conform to Section 26 05 53, Identification for Electrical Systems

2. Mimic bus: Apply continuously integrated mimic bus to the front of the switchgear. Arrange in single-line diagram format, using symbols and letter designations consistent with final mimic-bus diagram. Coordinate mimic-bus segments with devices in the section to which they are applied. Produce a concise visual presentation of principal components and connections:

   a. Mimic bus: Apply continuous mimic bus to the front of switchgear, arranged in single-line diagram format, using symbols and lettered designations consistent with approved final mimic-bus diagram.

   b. Medium: Painted graphics, as approved.

   c. Color: Contrasting with factory-finish background; selected by Engineer.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Ensure the unit substation assembly and switching components are certified to conform to applicable seismic requirements of IBC and as indicated on structural drawings.

B. Install each unit substation in a prepared concrete pad inside the substation building as indicated on the Contract Drawings.

C. Identify field installed conductors, interconnecting wiring and components and provide wiring signs in conformance with Section 26 05 53, Identification for Electrical Systems, and as indicated on the Contract Drawings.
D. Ground equipment: Section 26 05 26, Grounding and Bonding for Electrical Systems, and as indicated on the Contract Drawings.

E. Wiring Connections: Section 26 05 25, Wire and Cable.

3.02 FIELD QUALITY CONTROL

A. Prepare for acceptance tests as follows:

1. Test insulation resistance for each substation bus, component, connecting supply, feeder, and control circuit.

2. Test continuity of each circuit.

B. Manufacturer's field service: Engage a factory-authorized service representative to inspect cable connections and to assist in field testing. Report results in writing:

1. Verify the manufacturer's representative(s) is knowledgeable of each section of the unit substations.

2. Ensure the manufacturer's representative provides technical direction and assistance to the Contractor in cable connections and testing of the assembly and components contained therein.

3. Ensure the manufacturer's representative provides three copies of a written report on the operational testing of the equipment in accordance with the manufacturer's written instructions. Ensure the manufacturer's representative lists inspections and tests conducted and all results, including any problems found and how they were rectified. Ensure the manufacturer's representative certifies equipment is ready for acceptance testing.

C. Testing agency: Engage a qualified Independent Testing Laboratory to perform the following field tests and inspections and prepare test reports:

1. Use Independent Testing Laboratory and testing technician qualified in conformance to Section 26 08 00, Commissioning of Electrical Systems.

2. Ensure Independent Testing Laboratory performs visual and mechanical inspection and electrical test stated in NETA. Certify conformance to test parameters.

3. Ensure the Independent Testing Laboratory tests transformer in conformance with NETA 7.2.1.

4. Ensure the Independent Testing Laboratory tests incoming and outgoing switchgear in conformance with NETA, as appropriate.

5. Ensure the Independent Testing Laboratory sets field-adjustable circuit-breaker trip ranges.

6. Ensure the Independent Testing Laboratory tests and adjust controls and safeties.

7. Ensure the Independent Testing Laboratory performs the following infrared scan test and inspections and prepares reports:
a. Initial infrared scanning: After final inspection of the contract, but not more than 60 days after acceptance of contract, ensure the testing agency performs an infrared scan of each unit substation. Ensure the Independent Testing Laboratory removes front and rear panels so joints and connections are accessible to portable scanner.

b. Follow-up infrared scanning: Ensure the Independent Testing Laboratory performs an additional follow-up infrared scan of each unit substation 11 months after date of substantial completion.

c. Ensure the Independent Testing Laboratory uses an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. Ensure the Independent Testing Laboratory provides calibration record for device.

d. Ensure the Independent Testing Laboratory prepares a certified report that identifies unit substations included and that describes scanning results. Ensure the Independent Testing Laboratory includes notation of deficiencies detected, remedial action taken, and observations after remedial action.

D. Remove and replace malfunctioning units and components and retest as specified above.

1. Test reports: Prepare written reports to record the following:

   a. Test procedures used.

   b. Test results that comply with requirements.

   c. Test results that do not comply with requirements and corrective actions taken to achieve compliance with requirements.

   d. Provide three copies of the test report.

E. Voltage monitoring and adjusting: Perform the following voltage monitoring as a part of the overall systems commissioning, after all system components have been tested and accepted:

1. During a full load test, record for 10 minutes, the three-phase voltage at secondary terminals of each transformer. Use voltmeters with calibration traceable to National Institute of Science and Technology standards and with a chart speed of not less than 25 mm per hour. Voltage imbalance greater than 1 percent between phases, or deviation of any phase voltage from nominal value by more than plus or minus 5 percent during test period, is unacceptable.

F. Corrective actions: If test results are unacceptable, perform the following corrective actions, as appropriate:

1. Adjust transformer taps.

G. Retests: After corrective actions have been performed, repeat monitoring until satisfactory results are obtained.

H. Reports: Prepare a written report covering monitoring and corrective actions performed.
3.03 CLEANING

A. On completion of installation, inspect interior and exterior of the unit substations. Remove paint splatters and other spots. Vacuum dirt and debris and do not use compressed air to assist in cleaning. Repair exposed surfaces to match original finish.

3.04 DEMONSTRATION

A. Engage a factory-authorized service representative to Sound Transit's maintenance personnel to adjust, operate, and maintain unit substations, switching controls, overcurrent protective devices, instrumentation, and accessories. Provide up to two training classes of 4 hours each, including instruction materials.

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 load centers, and switchboards

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.

1.02 REFERENCES

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

1. American National Standards Institute (ANSI):
   a. ANSI C39.1 Requirements for Electrical Analog Indicating Instruments

   a. ASTM A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM B 187 Specification for Copper Bar, Bus Bar, Rod and Shapes

3. Institute of Electrical and Electronics Engineers (IEEE):

4. National Electrical Contractors Association (NECA):
   a. NECA 400 Recommended Practice for Installing and Maintaining Switchboards

5. National Electrical Manufacturers Association (NEMA):
   a. NEMA PB 1 Panelboards
   b. NEMA PB 2 Deadfront Distribution Switchboards
   c. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

   a. NFPA 70 National Electrical Code
7. Underwriters Laboratories (UL):
   a. UL 489 Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures

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. 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: Submit shop drawings and electrical diagrams as follows:
   1. Panelboards and Load 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.
   2. Circuit Breakers: Show circuit for which intended, voltage ratings, insulation level, current rating, and interrupting ratings.
   3. Switchboards
      a. Single line diagrams;
      b. Physical arrangement drawings, and weight of equipment and major components;
      c. Unit wiring diagrams;
      d. Show space available for conduit entrance and for routing and training of cables. Take into consideration bending radius requirements of cables when determining available space;
      e. Schematic diagrams for electrically operated equipment;
      f. Setting diagrams and templates if anchoring in concrete is required;
      g. Assembly and erection diagrams if shipped in sections or if any parts are shipped separately and not installed at the factory; and
h. Interconnection diagrams for circuits having externally located instruments, controls, alarms, or similar devices.

D. Operation and Maintenance Data: Submit data in accordance with Section 01 78 23, Operation and Maintenance Data, including the following requirements:

1. Description of the switchboard and its components;
2. Manufacturer's operating and maintenance instructions, parts list, illustrations, and diagram for components;
3. Recommended list of spare parts;
4. Wiring diagram;
5. Electrical characteristics of each component including relays or solid-state circuitry; and
6. Relay coordination curves.

E. Test Reports: Submit copies of certified reports of factory and field tests performed in accordance with the applicable referenced standards and specification requirements.

F. Shipping Record: Submit impact record chart to the Resident Engineer.

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 UL 489, NEMA PB 1, 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.

C. Special requirements for switchboards

1. Clearly label temporary internal bracing of equipment as "Temporary Bracing: To Be Removed Before Operation."

2. Use a mechanical impact recorder during shipment, capable of registering maximum acceleration.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Enclosed Circuit Breakers:
1. UL 489, molded case, quick-make quick-break bolt-on type, with thermal-magnetic type overload trip, interchangeable unit for frame rated 125 A and above.

2. Enclosure: NEMA 250 Type 12, fabricated from galvanized steel, surface-mounted unless otherwise indicated.

3. 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 Load Centers: NEMA PB 1.

1. Enclosure: NEMA 250 Type 12, fabricated from galvanized steel, surface-mounted unless otherwise indicated, tamperproof, with the following additional requirements:
   
   a. 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>

   b. Provide backplate of reinforced steel for mounting of interior components.

   c. Provide device or mechanism for enclosure grounding.

2. Cover and Trim:
   
   a. Designed for surface or flush mounting as indicated.

   b. Adjustment: Provide flush-mounted panelboards with means to plumb and align the front of the panel with respect to the adjacent finished surfaces.

   c. 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.

   d. Circuit Directory: Provide a directory frame with acrylic plastic face mounted on the back of the door.

   e. Finish: metallic surface thoroughly cleaned, degreased, primed with an approved corrosion-inhibitive primer, and then finished with heavy-duty, industrial-grade polyurethane enamel.

   
   a. Provide neutral bus of the same rating as that of phase bus.

   b. Provide a grounding bus.
4. Circuit Breakers  
   a. Bolt on type.  
   b. 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).

C. Switchboards:  
   1. Metal-enclosed, self-supporting, dead front, freestanding, circuit-breaker type for indoor service. Comply with NEMA PB 2, the National Electrical Code, and the authority having jurisdiction.  
   2. Provide the required number of vertical sections designed for bolting together to form a rigid switchboard.  
   3. Ensure switchboards are assembled, wired, and tested at the manufacturer's plant. If approved by the Resident Engineer, switchboards may be broken down into convenient shipping sections subsequent to the completion of the tests. Ensure split terminals and connections disconnected for shipping are properly identified and protected.  
   4. Ensure switchboards in the same line-up fed electrically from different feeders are installed with barriers such that a fire caused by an internal fault at one switchboard can not spread to another switchboard.  
   5. Current rating: Based on operation in a 25 degrees C room ambient.  
   6. Enclosure: Freestanding type, designed for group assembly to be part of complete indoor ac distribution, with the following additional requirements:  
   7. Physical Size: 90 inches high, with width and depth adequate to accommodate and connect the equipment. Align vertical sections front and rear, and equip with rear doors.  
   8. Reinforce with adequate steel framework to form a rigid structure with a smooth outer surface free from burrs, ridges, and other blemishes.  
   10. Finish: To finish metallic surfaces, clean, degrease, treat with hot phosphate chemical bath, prime with corrosion-inhibiting undercoat primer, and paint with finish coat of heavy-duty, industrial-grade, polyurethane enamel, in standard color as selected by the Resident Engineer.  
   11. Nameplates:  
      a. Provide a nameplate on each switchboard and its components as indicated.  
      b. Attach laminated plastic nameplates by means of stainless steel machine screws or rivets, or permanent adhesive.
c. Label each switchboard section with 4-inch wide nameplate showing switchboard number in 2-1/2-inch high white cut-in letters on black background.

d. Label each control switch and pilot light with 1-inch wide nameplate showing the function and the number of unit in 1/2-inch high white cut-in letters on black background.

12. Space Heater: Provide a thermostatically controlled space heater having capacity sufficient to maintain interior temperature above dew point in each cubicule. Space heater rated voltages as follows:
   a. Heaters 1.8 kW and over: 480 V, 3 phase.
   b. Up to 1.8 kW: 208 V, 3 phase.
   c. Up to 200 W: 120 V, single phase.

D. Switchboard Circuit Breakers:
   1. Fixed-mounted, insulated-case, stored energy, electrically operated type, 3 phase, 60 Hz, in accordance with NEMA PB 2.
   2. Maximum of 5-cycle closing time.
   3. Equip with solid-state trip unit with voltage and current sensors as indicated, and a minimum of seven time/current systems coordination adjustment, including ground fault and undervoltage settings.
   4. Ensure insulation rating of plug is the same as the breaker rating.
   5. Ensure circuit breakers are capable of performing 4,000 close-open cycles at rated load, 80 percent power factor and rated voltage, and 4,000 close-open cycles at no load without maintenance or replacement of parts.
   6. Ensure Breakers have control power and motor charging device of 120 V ac.
   7. Equip breakers with field-replaceable contacts.

E. Switchboard Buses:
   1. Provide silver-plated copper buses of sufficient size to limit the current density to 750 A per square-inch cross section.
   2. Brace distribution switchboard buses for the symmetrical fault current indicated.
   3. Main Buses: Extend main buses horizontally from the incoming line sections to all distribution sections if indicated on the same line-up. Make provision for extending the main buses for future vertical sections.
   4. Section Buses: Extend section buses vertically from the main bus through each vertical section.
   6. Ground Buses: Extend a ground bus through the length of the switchboard and firmly bolt to each vertical section in at least two places. Make provision for
connection to the building or station grounding system near each end of the ground bus. Make provision for future extension of the ground bus.

7. Phasing: Phase buses A-B-C from left-to-right, top-to-bottom, and front-to-rear as viewed from the front of the switchboard.

F. Switchboard Instruments, Control, and Accessories:

1. Potential Transformers: IEEE C57.13, wound type with polarity markers, suitable for operating meters and relays.
   a. Voltage: 120 V secondary.
   b. Insulation class: 600 V with basic impulse insulation level of 10 kV full wave.
   c. Temperature Rise: Ensure that the maximum allowable temperature rise not exceed 55 degrees C under continuous full load above an average ambient temperature of 25 degrees C.
      1) Winding average: 30 degrees C.
      2) Hottest spot in winding: 40 degrees C.

G. Current Transformers:

1. Type: Bushing or epoxy encapsulated wound.
2. Comply with IEEE C57.13 requirements for relaying accuracy classification under the burdens imposed by the devices specified or implied herein.
3. Use current transformers capable of withstanding thermal and magnetic stresses from the flow of the interrupting and momentary currents of the circuit breakers.
4. Locate current transformers in a separate compartment isolated from the meter section. Provide metallic shielding to protect current transformers and secondary wiring from induced voltages and to minimize the possibility of insulation failure.
5. Supply secondary terminal blocks with covers that have integral shorting bars. Connect secondary wiring to readily identifiable terminal block points in the control compartment. Ensure terminal block points have integral shorting bars for the current transformer leads.
6. Ensure current transformers have a mounting frame bolted securely to the switchgear frame.

H. Meters:

1. Type: ANSI C39.1, square, taut band, transformer rated, ironvane.
2. Dial: Approximately 4-1/2 inches square, graduated from zero to full range with black figures on white background.
3. Voltmeter rating: 600 V.
4. Ammeter rating: 125 percent of circuit rating, or as indicated.
5. Accuracy Class: 1 percent of full scale.
I. Relays:
   1. Provide one lock-out relay for preventing the breaker from reclosing after abnormal conditions, except undervoltage.
   2. Provide one time delay relay, adjustable from 0 to 6 seconds, for use with undervoltage relay.

J. Control Switches:
   1. Provide control switch as required and indicated.
   2. Provide relay test switch.
   3. Provide manual pushbutton at the front of breaker housing for testing breaker.

K. Control and Instrumentation Wiring:
   1. Factory Installed
   2. Wire: Type SIS tinned copper wire not smaller than 14 AWG. For wiring across hinged joints use Class D stranded wire, not smaller than 12 AWG.
   3. Wire Terminals: Tinned copper ring compression terminals with insulated sleeve installed in accordance with the manufacturer's recommendations.
   4. Terminal Blocks: Provide washerhead screws suitable for ring compression terminals with insulated sleeve. Provide a minimum of 10 percent spare terminals.
   5. Position Switch and Auxiliary Contacts: Provide position switch and breaker auxiliary contacts as indicated.
   6. Wire Connections: Wire controls, relays, and metering circuit terminals requiring external connections to accessible terminal blocks. Provide interconnecting wires terminated on terminal blocks in each cubicle.
   7. Wire Identification: Provide each wire with plastic sleeve, attached within 6 inches of terminal connections, and printed with the number indicated on the wiring diagrams.

L. Fuses: Provide current limiting fuse in each control circuit.

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 Hz 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. 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 multisectional panelboards and load centers to meet these spacings if necessary. Line up tops of trims to present neat appearance.

B. Anchor in accordance with seismic requirements in Section 26 05 00, Common Work Results for Electrical.

C. 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.

D. Connect neutral wires of branch circuits to the neutral bar of the same panelboard as the branch circuit.

E. 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.

F. 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.

G. Provide each panelboard and load center with an accurate typewritten circuit directory. Install in the factory-provided directory frame mounted on the back of the door.

H. Install switchboards in the locations indicated in accordance with NECA 400.

I. Anchor in accordance with seismic requirements in Section 26 05 00, Common Work Results for Electrical.

J. Install switchboard on a 4-inch high concrete pad with leveling channels.

K. 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.

L. Install supporting members, fastenings, framing, hangers, bracing, brackets, straps, bolts, and angles as required to set and rigidly connect the switchboard.

M. Exercise special care during construction to avoid overloading any part of the structure. Repair or replace items damaged due to overloading.

N. Field Touch up Painting: After installations are complete, thoroughly clean surfaces where shop finish is damaged, including bolts, nuts, washers and welds, and paint each item with the same paint system as used for shop painting. Provide touch-up painting by approved spray methods, or by brush where spray-painting is not practical.

O. Energizing Switchboards:
1. Perform pre-energizing checkout procedure in accordance with NECA 400 prior to energizing switchboards.

2. Notify Resident Engineer prior to energizing switchboards.

3. Energize switchboards in accordance with NECA 402.

### 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 Enclosed 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 load 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.

2. Switchboards:
   a. Verify that circuits are connected in accordance with the applicable wiring diagrams.
   b. Verify that circuits are continuous and free from short circuits.
   c. Verify that the insulation resistance to ground of non-grounded conductors is megger tested to not less than 10 megohms.
   d. Verify that the completed equipment grounding system is megger tested at each service disconnect enclosure ground bar to ensure connection to ground.
   e. Verify that circuits are operable. Conduct tests to include operating each control not less than ten times, and the continuous operation of each lighting and power circuit for not less than 1/2 hour.

**END OF SECTION**
SECTION 26 24 14
MOTOR STARTERS FOR TUNNEL FIRE VENTILATION FANS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing individual enclosed motor soft starters for Emergency Ventilation Fans and Smoke Exhaust Fans, including all components for fully functional self contained units ready for field installation and wiring as indicated in 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 26 05 00, Common Work Results for Electrical.
2. Section 26 05 53, Identification for Electrical System.

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 ICS 1, General Standards for Industrial Control and Systems
   b. NEMA ICS 1.1, Safety Guidelines for the Application, Installation, and Maintenance of Solid State Control
   c. NEMA ICS 2, Industrial Control Devices Controllers and Assemblies
   d. NEMA ICS 4, Terminal Blocks for Industrial Control
e. NEMA ICS 6, Industrial Controls and Systems Enclosures
f. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum)

5. Underwriters Laboratories, Inc. (UL):
a. UL 508, Industrial Control Equipment.

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. Shop Drawings: Submit shop drawings and electrical diagrams, including point to point wiring diagrams. Identify electrical characteristics and ratings of all component assemblies on shop drawings.

C. Product Data: Submit 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. Description 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: Submit certified test reports of shop and field tests performed, verifying that performance of equipment meets specification requirements.

F. Warranties

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 soft starters in secure and dry storage facility.

1.05 MEASUREMENT AND PAYMENT:

A. The work of this Section consists of providing complete and fully operable enclosed controllers/soft starter units for Emergency Ventilation Fans and Smoke Exhaust Fans as described in this specification, and as indicated on the Contract Drawings. The scope shall include controller enclosure design, fabrication, component procurement and assembly, circuit design, wiring, software design and programming, furnishing, installing, shop and field testing, and commissioning.
PART 2 - PRODUCTS

2.01 MANUFACTURERS:

A. The low voltage enclosed motor controllers shall be manufactured by any of the following:
   1. Allen-Bradley
   2. Eaton/Cutler Hammer
   3. ABB
   4. GE
   5. Or approved equal

2.02 MATERIALS

A. Motor Soft Starter Units
   1. Ensure motor starters meet the requirements of NEMA ICS 2, general purpose Class A, and the following additional requirements:
      a. Rating: Continuous current rating suitable for associated motors as follows:
         1) Emergency Ventilation Fans (EMFN) – 400hp
         2) Smoke Exhaust Fans (SEFN) – 100hp
      a. Type: For damp and dusty indoor location: NEMA 250, Type 12. Enclosure shall be free standing, bolted to the 4” high maintenance concrete pad
      c. Finish: Painted finish for all ferrous and galvanized metal surfaces.
         1) Prepare ferrous metal surfaces for painting in accordance with standard industry practice.
         2) Prepare galvanized metal surfaces for painting in accordance with ASTM D2092.
         3) After pretreatment, prime-paint surfaces with an approved corrosion-inhibitive metal primer for ferrous or galvanized surfaces, as applicable.
         4) For the finish coat use heavy-duty, industrial-grade polyurethane enamel.
      d. Dimensions: Per manufacturer.
e. The enclosure shall have full length hinged and gasketed front door with full length piano hinge and three point lockable door latching mechanism.

f. The door shall have a cut-out suitable for a panel/door mounted Motor Protection Relay (MPR) as shown on the Contract Drawings.

B. Motor Soft Starters for Emergency Ventilation Fans (MSS-EMFN)

1. MSS-EMFN units shall contain the following internal components:
   a. Fused Disconnect Switch
   b. Soft Starter with By-Pass Contactor
   c. Reversing Contactors
   d. Motor Protection Relay
   e. Control Power Transformer
   f. DC Power Supply – for soft starter.
   g. Terminal Blocks for internal & external control, protection and instrumentation wiring
   h. Internal control, protection and instrumentation wiring.
   i. Internal power interconnections
   j. Provisions for external power wiring

2. Fused Disconnect Switch:
   a. Type: Rotary, base mounting, fusible switch.
   b. Frame: F
   c. Current Rating: 800 Amp
   d. Rated Voltage: 600 Volt, 3 Phase, 60 Hertz
   e. Maximum 3-Phase Horsepower Rating at 480V: 400hp
   f. Short Circuit Rating: 200kA
   g. Fuse Type and Rating: Type J, 800A (for short-circuit and ground fault protection)
   h. The disconnect switch shall be UL Approved.
   i. Provide disconnect switch with heavy duty pistol handle and terminal lugs for three (3) 300kcmil cables per phase at line and load connections.

3. Soft Starter with By-Pass Contactor
   a. Type: Severe Duty Open type Multi-functional, Programmable, Reduced Voltage, Solid-State Motor Starter (Soft Starter).
b. Frame Size: V

c. Current Rating: 600 Amp

d. Operating Voltage: 200 - 600 Volt, 3 Phase, 60 Hertz

e. Maximum 3-Phase Horsepower Rating at 460V, 60 Hertz and 1.15SF: 450hp

f. Ramp Time: 30 seconds

g. Adjustable Ramp Time Range: 0.5 – 180 seconds

h. Ramp Current: 450% of FLA

i. Starts per Hour: 4

j. Control Power: 24Vdc

k. Auxiliary Contacts: 1 Class A and 1 Class C rated for 120Vac, 3amp.

l. The Soft Starter shall be UL Listed.

m. Provide Soft Starter with built-in Run Bypass Contactor and terminal lugs for three (3) 4/0 cables per phase at line and load connections.

4. Reversing Contactors

a. Type: Open type, Vertical Reversing Contactor

b. NEMA Size: 6

c. Current Rating: 600 Amp

d. Short Circuit Rating: 100 kA (with Class J Fuse specified above)

e. Operating Voltage: 600 Volt, 3 Phase, 60 Hertz

f. Maximum 3-Phase Horsepower Rating at 460V, 60 Hertz: 400 hp

g. Coil Voltage / Hz: 120 Volt 60, Hertz

h. Auxiliary Contacts: Type W Auxiliary Contact Modules with four (4) NO and four (4) NC contacts rated for 120Vac, 6 amp; for customer wiring.

i. The Reversing Contactor shall be UL Listed.

j. Provide Reversing Contactor with built-in Mechanical Interlock, interconnecting bus-bars and terminal lugs for three (3) 300kcmil cables per phase at line and load connections.

5. Motor Protection Relay

a. A microprocessor based Motor Protection Relay (MPR) shall be provided in each motor starter for protection, control and metering/monitoring of the fan motor.

b. The true rms current into the motor shall be constantly monitored, and by means of a protective algorithm, separated into positive and negative
sequence components. These components shall be used to determine the heating effects on the stator and rotor of the motor to provide maximum motor protection and utilization. The relay shall be capable of being connected by three-wire conductor or fiber optic to a remote Resistance Temperature Detection Module (RTDM) located at the motor to monitor up to six (6) motor winding, four (4) bearing and one (1) auxiliary RTD inputs and of providing similar function set point discrete outputs to the Programmable Logic Controller (PLC) at the Fan and Damper Local Control Panel (FDCP). The MPR shall integrate the temperature input data from the RTDM with the protective algorithm. The protective curve algorithm shall be adaptive based on the motor temperature as measured by the RTD. The protective algorithm shall provide faster trip times for higher temperatures providing maximum motor protection and shall operate with a longer trip time for lower temperatures allowing maximum motor utilization. The MPR shall provide the following protective functions:

1) Motor running time overcurrent/instantaneous protection, device 50/51
2) Adjustable instantaneous overcurrent protection, device 50G with adjustable start delay in one-cycle increments
3) Adjustable current unbalance protection, device 46
4) Locked rotor devices 48/51 LR
5) Under load trip with start and run time delays, device 37/2
6) Auxiliary overtemperature protection with RTDM
7) Stator protection with RTDM, device 49
8) Motor bearing over temperature protection with RTDM, device 38
9) Incomplete sequence relay, device 48
10) Limitation on number of starts per time period in minutes, device 66
11) Programmable transition relay based on current and/or time.
12) Time between starts
13) Number of cold starts
14) Zero speed switch input timer for use with long accelerating time motors

c. The MPR shall be programmed to disable or by-pass all temperature derived protective functions when an EMERGENCY signal is received from the remote control locations, thus allowing the fan motor to continue to run when the fan is exposed to high temperature gases produced by fire in tunnel or station.
d. Two user-programmable discrete inputs shall be provided for external control or trip functions. Programmable input functions shall be included for shutdown based on external contacts for incomplete sequence of operation and remote trip, remote closed, motor stop, reset disable, zero speed switch or emergency override.

e. The MPR shall be capable of accommodating external current transformers with rating as indicated on the Contract Drawings or as recommended by the manufacturer based on the motor full-load amperes and service factor. A separate zero sequence current transformer rated at 50/5 shall also be provided.

f. MPR Operating Voltage: 120 Vac, 60 Hertz

g. MPR, including all its modules and the user interface shall be door mounted, on the MMS-EMFN enclosure as shown on the Contract Drawings. The MPR user interface and all its functions shall be accessible from the front of the MMS-EMFN enclosure.

h. The MPR shall have a real-time clock for time tagging of events, operations and history. The relay shall have quick and easy access to monitored values, view settings, motor history and motor log records. The relay shall monitor and display the following:

1) Motor currents: Average current (Iave), individual phase and ground current in primary amperes and percent of full load and percent phase unbalance

2) Motor RTD: Individual winding, motor bearing, load bearing and auxiliary temperatures

3) Motor: Percent I2t (thermal accumulation), time until next start can occur, remaining number of starts, and time left on oldest start.

i. The MPR shall be capable of providing a 4 – 20 mA output signal proportional to the average of the three-phase currents for tripping and alarming on any transducer input such as vibration, pressure and air flow.

j. Provide an addressable communications card capable of changing set points, transmitting all data, including trip/alarm data, a starting profile of the average phase current for the two most recent starts, all over a two-wire area network (RS485 and RJ45 Ethernet) to the Fan and Damper Local Control Panel for storage and/or printout. The network shall also be capable of transmitting data in RS-232 format via a translator module.

k. The MPR shall provide the following data logging and display capability for history including the date and time from when the history was last reset and counting began. The history shall include:

1) Resettable motor history for operational counter, run time, highest starting and running currents, highest percent phase unbalance, maximum winding, bearing and load RTD temperature, and number of emergency overrides
2) Re-settable Trip history for number of trips for ground faults, overloads, time and instantaneous overcurrent, underload, phase unbalance, RTDs, phase reversal, incomplete sequence, communication, starts exceeded, time between starts, and transition.

3) Re-settable Alarm history for number of alarms, for ground faults, overloads, underload, phase unbalance, RTDs, starts exceeded.

4) A permanent history record which cannot be reset shall include total trips, run time and operations count.

5) A log book including a chronological list of events or operations as detected by the MPR, such as, starts, stops, setting change, emergency override, trips, alarms or changes in the state of discrete inputs.

6) An event log providing detailed information on trips and alarms including phase and ground currents, percent phase unbalance, maximum RTD temperatures, and cause of trip or alarm.

7) A start log providing information on the four most recent starts including maximum phase and ground starting current, maximum percent unbalance, time from start to transition, current at transition, and time from start to run or trip.

l. The MPR unit shall have separate Form C (NO/NC) Trip, two programmable Form C (NO/NC) Alarm and Auxiliary contacts. All contacts shall have ratings of 10-amperes at 120/240 Vac resistive. The alarm and auxiliary relay output contacts shall be programmable to operate from any internal protection function or from a discrete input signal such as remote trip.

m. Entered data shall be stored in non-volatile memory so as not to require battery backup. Non-volatile memory shall be capable of storing all setup information even after power failure, all monitored information at the time of a trip, and cause of trip even after power failure. Access to all programmed set points shall be restricted by means of a secured and sealed access cover.

n. Alphanumeric display shall read out (in English) complete description of all protective functions e.g., “instantaneous overcurrent” and all monitored and programmable data such as “percent of full load in amps” and “motor bearing temperature”.

o. The MPR shall have a user-programmable armed/disarmed feature with alarm indication. The disarmed mode shall permit relay installation while the motor is running with the trip outputs blocked. The draw-out case shall have a spare self-shorting contact to allow for continuous motor running or relay removed alarm functions.

p. The MPR user interface shall provide for starting of the fan in forward or reverse direction, for stopping of the fan and for motor status indication. It shall have a full color graphical display motor and system status LED’s and USB programming port.

q. The MPR shall be UL Listed.
6. Control Power Transformer
   a. Control power shall be 120 Vac obtained from integral control power transformer (CPT). Include control power transformer with adequate capacity to operate connected control, indication and protection devices, plus 100 percent spare capacity.
   b. The dry-type CPT shall be a minimum of 1000 VA, 480 -120V, single phase, 60 Hertz.
   c. Appropriately sized primary and secondary fuses shall be provided.
   d. The primary side of the control power transformer shall be protected by current limiting fuses sized according to the requirement.
   e. The secondary side of the control power transformer shall be fused appropriately to protect the transformer from overloads.
   f. The standard control circuit shall have one leg of the secondary grounded.

7. DC Power Supply
   a. Provide a 24Vdc power supply for the soft starter
   b. Input/Output: 115Vac input, 24Vdc output
   c. Steady state wattage: As required, a minimum of 55W
   d. Inrush wattage: 250W

8. Terminal Blocks for internal & external control, protection and instrumentation wiring
   a. Terminal blocks shall be double-row collar type screw terminals with spring action overlapping top plates rated for 30 amperes, 600 volts with barrier strips between each adjacent row of terminal positions. Terminal blocks shall conform to NEMA ICS-4 and UL 50. Each terminal shall have a white marking strip and plastic cover.
   b. Provide terminal blocks with sufficient terminal points for all required wiring interconnections.
   c. Provide 25 percent spare terminals. Mount terminal blocks securely to bracket assembly with stainless steel screws and washers. Terminals shall be grouped and segregated for different operating voltages.
   d. Verify that each terminal block is able to accommodate two 14 AWG wires.

9. Internal control, protection and instrumentation wiring.
a. For the control wiring inside the controller enclosure use minimum 16 AWG, stranded, thermoplastic-insulated wire, rated 105 degrees C, with red color for ac.

10. Internal power interconnections
   a. Internal power interconnections shall be made with insulated bus-bars or insulated cable rated for motor FLA.

11. Provisions for external power wiring
   a. The controller Line and Load terminals arrangement shall allow adequate space for field termination of external power wiring.

C. Motor Soft Starter for Smoke Exhaust Fans (MSS-SEFN)

1. MSS-SEFN units shall contain the following internal components:
   a. Fused Disconnect Switch
   b. Soft Starter with By-Pass Contactor
   c. Motor Protection Relay
   d. Control Power Transformer
   e. DC Power Supply – for soft starter.
   f. Terminal Blocks for internal & external control, protection and instrumentation wiring
   g. Internal control, protection and instrumentation wiring.
   h. Internal power interconnections
   i. Provisions for external power wiring

2. Fused Disconnect Switch:
   a. Type: Rotary, base mounting, fusible switch.
   b. Frame: V
   c. Current Rating: 200 Amp
   d. Rated Voltage: 600 Volt, 3 Phase, 60 Hertz
   e. Maximum 3-Phase Horsepower Rating at 480V: 125hp
   f. Short Circuit Rating: 200kA
   g. Fuse Type and Rating: Type J, 200A (for short-circuit and ground fault protection)
   h. The disconnect switch shall be UL Approved.
   i. Provide disconnect switch with heavy duty pistol handle and terminal lugs for 250 kcmil cables at line and load connections.
3. **Soft Starter with By-Pass Contactor**
   a. Type: Severe Duty Open type Multi-functional, Programmable, Reduced Voltage, Solid-State Motor Starter (Soft Starter).
   b. Frame Size: T
   c. Current Rating: 150 Amp
   d. Operating Voltage: 200 - 600 Volt, 3 Phase, 60 Hertz
   e. Maximum 3-Phase Horsepower Rating at 460V, 60Hertz and 1.15SF: 100hp
   f. Ramp Time: 30 seconds
   g. Adjustable Ramp Time Range: 0.5 – 180 seconds
   h. Ramp Current: 450% of FLA
   i. Starts per Hour: 4
   j. Control Power: 24Vdc
   k. Auxiliary Contacts: 1 Class A and 1 Class C rated for 120Vac, 3amp.
   l. The Soft Starter shall be UL Listed.
   m. Provide Soft Starter with built-in Run Bypass Contactor and terminal lugs for 500kcmil cables at line and load connections.

4. **Motor Protection Relay**
   a. Except for Current Transformer ratings, the MPR for SEFN controller is similar to MPR for EMFN controller and shall be as specified in Article B.5 above.

5. **Control Power Transformer**
   a. Control power shall be 120 Vac obtained from integral control power transformer (CPT). Include control power transformer with adequate capacity to operate connected control, indication and protection devices, plus 100 percent spare capacity.
   b. The dry-type CPT shall be 300 VA, 480 -120V, single phase, 60 Hertz.
   c. Appropriately sized primary and secondary fuses shall be provided.
   d. The primary side of the control power transformer shall be protected by current limiting fuses sized according to the requirement.
   e. The secondary side of the control power transformer shall be fused appropriately to protect the transformer from overloads.
   f. The standard control circuit shall have one leg of the secondary grounded.

6. **DC Power Supply**
a. Provide a 24Vdc power supply for the soft starter.

b. Input/Output: 115Vac input, 24Vdc output

c. Steady state wattage: As required, a minimum of 55W

d. Inrush wattage: 250W

e. The DC Power Supply shall be Cutler-Hammer Catalog Number PSS55A or approved equal.

7. Terminal Blocks for internal & external control, protection and instrumentation wiring

a. Terminal blocks shall be double-row collar type screw terminals with spring action overlapping top plates rated for 30 amperes, 600 volts with barrier strips between each adjacent row of terminal positions. Terminal blocks shall conform to NEMA ICS-4 and UL 50. Each terminal shall have a white marking strip and plastic cover.

b. Provide terminal blocks with sufficient terminal points for all required wiring interconnections.

c. Provide 25 percent spare terminals. Mount terminal blocks securely to bracket assembly with stainless steel screws and washers. Terminals shall be grouped and segregated for different operating voltages.

d. Verify that each terminal block is able to accommodate two 14 AWG wires.

8. Internal control, protection and instrumentation wiring.

a. For the control wiring inside the controller enclosure use minimum 16 AWG, stranded, thermoplastic-insulated wire, rated 105 degrees C, with red color for ac.

9. Internal power interconnections

a. Internal power interconnections shall be made with insulated bus-bars or insulated cable rated for motor FLA.

10. Provisions for external power wiring

a. The controller Line and Load terminals arrangement shall allow adequate space for field termination of external power wiring.

PART 3 - EXECUTION

3.01 FABRICATION, ASSEMBLY AND TESTING

A. The Controller shall be fabricated and fully assembled at the supplier’s plant.

B. A shop test shall be performed and the test report approved prior to shipping to site. All devices, wiring and connections shall be functionally checked for proper operation in the manufacturing facility.
C. The shop test shall include a full load test with the actual fan for which it is intended or a load of equivalent mechanical/electrical characteristics.

D. The final shop test shall be witnessed by the Owner.

E. All inspections and tests at the manufacturing facility shall be documented and signed by qualified staff at the manufacturing facility.

3.02 INSTALLATION

A. Install individual motor controllers as indicated and as recommended by the manufacturer/supplier.

B. Anchor equipment in accordance with the seismic requirements in Section 26 05 00, Common Work Results for Electrical.

C. Motor Data: Provide label on each motor controller enclosure door in accordance with Section 26 05 53, Identification for Electrical Systems, and as indicated on the Contract Drawings.

3.03 ENERGIZING MOTOR CONTROL CENTERS

A. Perform pre-energizing checkout procedure in accordance with NECA 402 prior to energizing the motor controller.

B. Notify Resident Engineer prior to energizing motor controller.

C. Energize motor controllers in accordance with NECA 402.

3.04 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 nongrounded conductor is a minimum of 10 megohms.

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.

5. Demonstrate the specified controller operation to the satisfaction of the Resident Engineer.

3.05 DEMONSTRATION AND TRAINING:

A. Following installation, the Contractor shall make available the services of technician(s) to inspect the system installation and complete a thorough test and calibration of the system.
B. Contractor shall provide equipment demonstration and training for the Operation Engineer's maintenance personnel to adjust, operate, and maintain motor controllers, interlocking and controls, protective devices, instrumentation and accessories, and provide a minimum of 8 hours of training to the owner's personnel. A minimum of 3 full days shall be allowed for the completion of all start-up and training requirements.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for furnishing and installing enclosed switches and fuses.

1.02 REFERENCES
A. This Section incorporates by reference the latest revision 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 MATERIALS
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 as required for the environment or as designated on the Contract Drawings.
   
   a. **Type:**
      1) For dry and dust-free indoor location: NEMA 250, Type 1 with drip shield.
      2) For damp and dusty indoor location: NEMA 250, Type 12.
      3) For outdoor location: NEMA 250, Type 3R.
      4) For areas subject to corrosion: NEMA 250 Type 4X

4. Enclosures in escalator and elevator pits shall be rated NEMA 250 Type 12.

5. All equipment shall be rated for the available short circuit fault current.

**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.

2. Fuse sizes shown on plans have been sized at the maximum NEC allowance for time delay fuses (175%). Fuse sizes can be reduced for coordination purposes if allowed for by mechanical equipment manufacturer. Wire size shall not be reduced under any circumstances.

**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.

**END OF SECTION**
CONTRACT SPECIFICATIONS

SECTION 26 29 13
ENCLOSED CONTROLLERS

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. 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 53, Identification for Electrical System.

1.02 REFERENCES

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

   a. ASTM A 653/A 653M Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
   b. ASTM D 2092 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 ICS 2 Industrial Control Devices Controllers and Assemblies
   b. NEMA ICS 6 Industrial Controls and Systems Enclosures
   c. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

1.03 SUBMITTALS

A. Procedures: Section 01 33 00, Submittal Procedures.
B. Shop Drawings: Submit shop drawings and electrical diagrams. Identify relay characteristics, including inrush current rating, on shop drawings.

C. Product Data: Submit 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. Description 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: Submit certified test reports of factory and field tests performed, verifying that performance of equipment meets specification requirements.

F. Submit evidence of compliance to seismic safety requirements of the Washington State Building Code, local amendments thereto, and the National Electrical Code in conformance with Section 26 05 00, Common Work Results for Electrical.

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 starters, mcc's, control panels, and contactors in secure and dry storage facility.

PART 2 - PRODUCTS

2.01 MATERIALS

A. MOTOR STARTERS
   1. Ensure motor starters meet the requirements of NEMA ICS 2, general purpose Class A, and the following additional requirements:
      a. Rating: Continuous current rating suitable for associated motor as indicated. Provide heater sized for motor running protection based on duty rating and full-load current of supplied motor.
      a. Type:
         1) For dry and dust-free indoor location: NEMA 250, Type 1 with drip shield.
         2) For damp and dusty indoor location: NEMA 250, Type 12.
         3) For outdoor location: NEMA 250, Type 3R.
4) For areas subject to corrosion: NEMA 250 Type 4X


c. Finish: Painted finish for all ferrous and galvanized metal surfaces.

1) Prepare ferrous metal surfaces for painting in accordance with standard industry practice.

2) Prepare galvanized metal surfaces for painting in accordance with ASTM D 2092.

3) After pretreatment, prime-paint surfaces with an approved corrosion-inhibitive metal primer for ferrous or galvanized surfaces, as applicable.

4) For the finish coat use a heavy-duty, industrial-grade polyurethane enamel.

3. Provide auxiliary devices at each contactor meeting the following requirements:

a. Ensure auxiliary devices are manufacturer’s standard products. Ensure Control diagrams show actual configuration including auxiliary devices.

b. Heavy-duty type relay: Select devices with a Contact rating of 20 A at 120 V ac which operate satisfactorily at 120 degrees F.

4. Mount terminal blocks used at the contactor in the enclosure. Verify that each terminal block is able to accommodate two 14 AWG wires.

5. Wiring:

a. For the control wiring inside the contactor enclosure use minimum 16 AWG, stranded, thermoplastic-insulated wire, rated 221 degrees F, with red color for ac.

b. Use power cable of the same type and rating as control wiring, black color, and with capacity compatible with the contactor or breaker rating.

6. 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
8. Combination Motor Starters: Rated 480 V, three phase or single phase, 60 Hz. 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, as indicated, 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. Solid-State, Reduced Voltage controller (15 HP and larger motors)
   1. NEMA ICS 2, suitable for use with NEMA MG-1, Design B, polyphase, induction motors
   2. Adjustable acceleration rate control utilizing voltage or current ramp, and adjustable starting torque control with up to 500 percent current limitation for 20 seconds.
   3. Surge suppressor in Solid-State power circuits providing 3-phase protection against damage from supply voltage surges 10 percent or more above nominal line voltage.
   4. LED indicators showing motor and control status, including the following conditions:
      a. Control power available.
      b. Controller on.
      c. Overload trip
      d. Loss of phase
      e. Shortened silicon-controlled rectifier
   5. Automatic voltage-reduction controls to reduce voltage when motor is running at light load.
   6. Motor running contactor operating automatically when full voltage is applied to motor.

C. Lighting Contactors
   1. Contactors: NEMA ICS 2; electrically-held, two-wire control.
   2. Coil Operating Voltage: 120 volts, 60 Hertz.
   3. Contacts: Silver alloy, fully rated for tungsten lighting loads, 20A, 600 volts or as noted on Contract Drawings.
   4. Enclosure: NEMA 250, Type 12. Open-type contactors may be used when mounted within equipment enclosures as a listed assembly.
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 12 cabinet for control of lighting systems. Ensure the control panel includes LonWorks-based network lighting controller, individual low-voltage, mechanically-held relays rated for 20A 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 low-voltage power supply transformer/rectifier, interlocking relays, and terminal strips for interface with field wiring.
   d. Provide the following automatic and remote functions in the lighting control panel
      1) Provide a switch in the controller front cover to bypass normal controller operation and turn on all lights.
      2) Provide a daylight controller that can be configured to turn on all or certain of the lighting circuits.
      3) Provide stand-alone time control that can be used without a LonWorks network for any group of the controller outputs.

2. Supply the LonWorks-based network lighting controller to meet the following requirements:
   a. Automatic on/off control based on a time schedule and daylight sensor. Time of day that will be derived from an internal clock, with provisions for future synchronization to a system clock on the local LonWorks network. Daylight control that will be derived from a local sensor to be provided under this Contract.
   b. Override control of any output or group of outputs by other nodes on the LonWorks network.
   c. LonWorks network interface in the controller that is LonMark compliant.
      1) Provide at least one software object.
      2) If multiple objects are provided, also provide a node object.
      3) Use standard network variables and standard configuration properties wherever possible. Fully document all other custom variables and configuration properties.
      4) Ensure that no special software is required in order to use the controller. Ensure the network interface supports any standard LonWorks Network Services (LNS) tool.
5) Ensure the network interface provides a service button for identifying the node and a 'wink' LED for LonWorks status indication.

3. Provide a LonWorks device 'plug-in' to simplify controller configuration and set up certain automatic functions prior to installation of the LonWorks network. Set up plug-in to be an LNS application supplied by the device manufacturer and launchable by any LNS director application. Ensure the plug-in provide a graphical user interface to install and configure the controller and its functions.


PART 3 - EXECUTION

3.01 INSTALLATION

A. Size requirements

1. Motor starters shall not be smaller than size 1 for 480 V and size 0 for 120, 208 or 240 V ac.

2. For fractional horsepower loads rated at 120 V ac, single phase provide manual starters.

B. 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.

H. ENERGIZING MOTOR CONTROL CENTERS

1. Perform pre-energizing checkout procedure in accordance with NECA 402 prior to energizing motor control centers.

2. Notify Resident Engineer prior to energizing motor control centers.

3. Energize motor control centers in accordance with NECA 402.

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 nongrounded conductor is a minimum of 10 megohms.

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.

END OF SECTION
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PART 1 - GENERAL

1.01 SUMMARY

A. This section includes specifications for three-phase, on-line, static-type, uninterruptible power supply (UPS), complete with transient voltage surge suppression, input harmonics reduction, rectifier-charger, battery, battery disconnect device, inverter, static bypass transfer switch and maintenance bypass/isolation switch.

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 26, Grounding and Bonding for Electrical systems
2. Section 26 05 53, Identification for Electrical Systems.

1.02 REFERENCES AND STANDARDS

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

B. Applicable provisions of the following standards applies to the work of this Section, except as modified herein, and are hereby made a part of these Specifications to the extent required:

1. American National Standards Institute (ANSI):

2. National Electrical Manufacturers Association (NEMA):
   b. NEMA 250: Enclosure for Electrical Equipment.

3. Underwriters Laboratories Inc. (UL):
   a. UL 1778: Uninterruptible Power Supply Equipment.


5. Institute of Electrical and Electronic Engineers (IEEE):


7.  Federal Communications Commission (FCC):
   a.  FCC Part 15 Class A.

8.  National Institute of Standards and Technology (NIST)

1.03 DEFINITIONS
A.  EMI: Electromagnetic interference.
B.  LCD: Liquid-crystal display.
C.  LED: Light-emitting diode.
D.  THD: Total harmonic distortion.
E.  UPS: Uninterruptible power supply.

1.04 SUBMITTALS
A.  Procedures: Section 01 33 00, Submittal Procedures.
B.  Furnish the following:
   1.  Product Data: Include data on features, components, ratings, and performance for each uninterruptible power supply component indicated.
   2.  Shop Drawings: Detail assemblies of equipment indicating dimensions, weights, components, and location and identification of each field connection. Show access, workspace, and clearance requirements; details of control panels; and battery arrangement.
   3.  Wiring Diagram: Detail internal and interconnecting wiring, power, signal, and control wiring. Differentiate between field-installed and factory-installed wiring and components.
   4.  Dimensioned Outline Drawings of Equipment Unit: Identify weight and center of gravity and locate and describe mounting and anchorage provisions for each individual cabinet or enclosure.
   5.  Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
   6.  Manufacturer Certificates: Signed by manufacturers certifying that they comply with requirements.
   7.  Qualification Data: For firms and persons specified in “Quality Assurance” Article.
   8.  Factory Test Reports: Comply with specified requirements.
   9.  Field Test Reports: Indicate test results compared with specified performance requirements, and provide justification and resolution of differences if values do not agree.
10. Maintenance Data: For maintenance manuals specified in Division 1, General Requirements, include the following:
   a. List of spare parts and replacement components recommended being stored at project site for ready access.
   b. Detailed operating instructions covering operation under both normal and abnormal conditions.
   c. Warranties: Special warranties specified in this Section.

11. Manufacturer Seismic Qualification Certification: Submit certification that UPS equipment will withstand seismic forces in accordance with Uniform Building Code (UBC) for Washington State seismic zone three requirements.

1.05 QUALITY ASSURANCE
   A. Source Limitations: Obtain the UPS and associated components specified in this Section from a single manufacturer with responsibility for entire UPS installation.
   B. The supplier has a local service organization with factory-trained technicians and a local part inventory, and is capable of providing training, parts and emergency maintenance and repairs for equipment at the Contract site with 8 hours maximum response time.
   C. Installer Qualifications: An experienced installer who is an authorized representative of UPS manufacturer for both installation and maintenance of units required for this Contract for at least 5 years.
   D. Listing and Labeling: Provide electrical components, devices, and accessories that are Listed and Labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to the Authority Having Jurisdiction, and marked for intended use for the location and environment in which they are installed. The equipment is labeled “Suitable for use on emergency system” in accordance with NEC 700-3.

1.06 DELIVERY, STORAGE AND HANDLING
   A. Deliver equipment in fully enclosed vehicles after specified environmental conditions have been permanently established in spaces where equipment is to be placed.
   B. Store equipment in spaces with environments controlled within manufacturer’s ambient temperature and humidity tolerances for non-operating equipment.

1.07 PROJECT CONDITIONS
   A. Environmental Conditions: UPS is capable of operating continuously in the following environmental conditions without mechanical or electrical damage or degradation of operating capability, except battery performance.

   1. Ambient Temperature for Electronic Components: 32 to 104 degrees F.
   2. Ambient Temperature for Battery: 41 to 104 degrees F.
   3. Relative Humidity: 5 percent to 95 percent, noncondensing.
   4. Altitude: Sea level to 500 feet.
1.08 WARRANTY

A. Warranties, General: Special warranties specified in this Article is in addition to, and run concurrent with, other warranties made under requirements of these Specifications.

B. Special Battery Warranties: Written warranty, signed by manufacturer and Installer agreeing to replace UPS system storage batteries that fail in materials or workmanship within specified warranty period.

C. Warranted Cycle Life for Sealed Lead-Acid Batteries: Equal to or greater than that represented in manufacturer's published table based on annual average battery temperature of 77 degrees F.

D. Special UPS Warranties: Written warranties, signed by manufacturer and Installer agreeing to replace components that fail in materials or workmanship within special warranty period.

E. Special Warranty Period: two years from date of Substantial Completion.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Manufacturers: Subject to compliance with requirements, provide products by one of the following:

1. SolidState controls Inc.
2. Powerware.
3. Liebert Corp.
4. Controlled Power Company
5. Approved Equal

2.02 MANUFACTURED UNITS

A. Output Load Capacity: 1) Three Phase, 0.8 lagging power factor. 2) Single Phase, 0.8 lagging power factor. Refer to the Contract Drawings for the UPS ratings (voltage and KVA).

B. UPS will perform as specified in this Article while supplying rated full-load current, composed of any combination of linear and nonlinear load, up to 100 percent nonlinear load with a load crest factor of 3.0, under the following conditions or combinations of the following conditions:

1. Inverter is switched to battery source.
2. Steady-state ac input voltage deviates up to plus or minus 10 percent from nominal voltage.
3. Steady-state input frequency deviates up to plus or minus 5 percent from nominal frequency.
4. THD of input voltage is 15 percent or more with a minimum crest factor of 3.0, and the largest single harmonic component is a minimum of five percent of the fundamental value.
5. Output Frequency: 60 Hz plus/minus 0.5 percent over full range of input voltage, load and battery voltage.

6. Load is 50 percent unbalanced continuously.

C. Minimum Duration of Supply: If battery is sole energy source supplying UPS-rated full-output load current at 80 percent power factor, duration of supply is 90 minutes.

D. Input Voltage Tolerance: System steady state and transient output performance remains within specified tolerances when steady-state ac input voltage varies plus 10, minus 20 percent from nominal voltage.

E. Maximum Acoustical Noise: 65 dBA measured one meter from the surface of the UPS.

F. Maximum Energizing Inrush Current: Six times the full-load current.

G. Maximum AC Output-Voltage Regulation for Loads up to 50 percent Unbalanced: Plus or minus 2 percent over the full range of battery voltage.

H. Output Frequency: 60Hz, plus or minus 0.5 percent over the full range of input voltage, load, and battery voltage.

I. Maximum Harmonic Content of Output-Voltage Waveform: Five percent RMS total and three percent RMS for any single harmonic, for 100 percent rated nonlinear load current with a load crest factor of 3.0.

J. Minimum Overload Capacity of UPS at Rated Voltage: 125 percent of full-load rating for 10 minutes without bypass source, and 150 percent for 30 seconds without bypass source.

K. Input Power Factor: A minimum of 0.85 lagging when supply voltage and current are at nominal rated values and UPS is supplying rated full-load current.

L. EMI Emissions: Comply with FCC Rules and Regulations, 47 CFR 15 for Class A

M. Electronic Equipment: Solid-state devices using hermetically sealed, semiconductor elements. Devices include rectifier-charger, inverter, static bypass transfer switch, and system controls.

N. Enclosure: Comply with NEMA 250, Type 1, unless otherwise indicated.
   1. The cabinet doors and louvers require tools for access.
   2. Provide casters and leveling feet.
   3. Front access only for servicing.
   4. The overall enclosure width and depth will not exceed the space allocated on the Contract Drawings.

O. Control Assemblies: Mount on modular plug-ins, readily accessible for maintenance.

P. Surge Suppression: Protect internal UPS components from surges that enter at each ac power input connection including main disconnect, static bypass transfer switch, and maintenance bypass/isolation switch. Protect rectifier-charger, inverter, controls, and output components.
   1. Use factory-installed surge suppressors tested according to IEEE C62.41, Category B.
2. Additional Surge Protection: Protect internal UPS components from low frequency, high-energy voltage surges described in IEEE C62.41. Design the circuits connecting with external power sources and select circuit elements, conductors, conventional surge suppressors, and rectifier components and controls so input assemblies will have adequate mechanical strength and thermal and current-carrying capacity to withstand stresses imposed by 40-Hz, 180 percent voltage surges described in IEEE C62.41.

Q. Seismic-Restraint Design: UPS assemblies, subassemblies, and components; and fastenings and supports, mounting, and anchorage devices for them, are designed and fabricated to withstand static and seismic zone three forces in all directions.

R. UPS Cabinet Ventilation: Cooling of the UPS is by forced air. Low-velocity fans are used to minimize audible noise output. Fan power is provided by the UPS output. UPS cabinet ventilation shall be in compliance with the Seattle Mechanical Code Section 502.5.

S. Output Circuit Neutral Bus, Conductor, and Terminal Ampacity: Rated phase current times a multiple of 2.0, minimum.

T. Capacity Upgrade Capability
   1. Selected systems shall be capable to accept a field installed power upgrade to the next higher power rating without an increase in cabinet size.
   2. Capacity Upgrade Capability: Arrange wiring, controls, and modular component plug-in provisions to permit future 25 percent increase in UPS capacity.

U. Extra Materials
   1. Local field service organization shall stock extra materials described below that match products installed and that are packaged with protective covering for storage and identified with labels describing contents.
   2. Provide qualified service personnel available around-the-clock 365 days a year.
   3. Provide toll free direct phone number.
   4. Fuses: One for every ten of each type and rating, but not less than one of each.
   5. Cabinet Ventilation Filters: One complete set.
   6. One spare circuit board for each critical circuit.

2.03 COMPONENTS

A. Rectifier-Charger
   1. Capacity: Adequate to supply the inverter during full-rated output load conditions and simultaneously recharge the battery from fully discharged condition to 95 percent of full charge within ten times the rated discharge time for duration of supply under battery power at full load.
   2. Output Ripple: Limited by output filtration to less than 0.5 percent of rated current, peak to peak.
   3. Rectifier-Charger Control Circuits: Immune to frequency variations within rated frequency ranges of normal and emergency power sources.
a. Response Time: Field adjustable for maximum compatibility with portable generator-set power source.

4. Battery Float-Charging Conditions: Comply with battery manufacturer written instructions for battery terminal voltage and charging current required for maximum battery life.

B. Inverter

1. Description: Pulse-width modulated, with sinusoidal output.

2. Description: Pulse-width modulated, with sinusoidal output. Include a bypass phase synchronization window adjustment to optimize compatibility with portable engine-generator-set power source.

C. Static Bypass Transfer Switch

1. Description: Solid-state switching device providing uninterrupted transfer. A contactor or electrically operated circuit breaker automatically provides electrical isolation for the switch.

2. Switch Rating: Continuous duty at the rated full-load current of the UPS, minimum.

D. Battery

1. Description: Sealed, valve-regulated, recombinant, lead-calcium units, factory assembled in an isolated compartment of UPS cabinet, and complete with battery disconnect switch.

E. UPS Control and Indication

1. Provide system power flow diagram on front of cabinet.

2. Description: Group displays, indications, and basic system controls on a common control panel on front of UPS enclosure.

3. Minimum displays, indicating devices, and controls include those in lists below. Provide sensors, transducers, terminals, relays, and wiring required to support listed items. Alarms include an audible signal and a visual display.

4. Indications: Plain-language messages on a digital LCD or LED.

5. Dry-form “C” contacts are available for remote indication of the following conditions:
   a. UPS on battery.
   b. UPS on-line.
   c. UPS load-on bypass.
   d. UPS in alarm condition.
   e. UPS off (maintenance bypass closed).

F. Maintenance Bypass/Isolation Switch
1. **Description:** Manually operated switch or arrangement of switching devices with mechanically actuated contact mechanism arranged to route the flow of power to the load around the rectifier-charger, inverter, and static bypass transfer switch.
   
a. **Switch** are interlocked to prevent interrupting power to the load when switching to the bypass mode.

b. **Switch** shall isolate other UPS components electrically to permit safe servicing.

2. **Comply with NEMA PB 2 “Dead-Front Distribution Switchboards” and UL 891 “Dead-Front Switchboards”**.

3. **Switch Rating:** Continuous duty at rated full-load current of UPS.

4. **Mounting Provision:** Internal to system cabinet or external wall mount.

5. **Key interlock requires unlocking maintenance bypass/isolation switch before switching from normal position with key that is released only when the UPS is bypassed by static bypass transfer switch.** Lock is designed specifically for electrical component interlocking.

**G. Monitoring by Remote Computer**

1. **Description:** Communication module in unit control panel would provide capability for remote monitoring of status, parameters, and alarms. The remote computer and the connecting signal wiring are not included in this Section. Include the following features:

   a. LON Mark compatible network interface units, or Approved Equal.

   b. Software designed for control and monitoring of UPS functions and to provide on-screen explanations, interpretations, diagnosis, action guidance, and instructions for use of monitoring indications and development of meaningful reports. Permit storage and analysis of power-line transient records. Design for Microsoft Windows or approved equal application in an IBM-compatible computer, which is not included in this Section.

**H. Basic Battery Monitoring**

1. **Battery Ground-Fault Detector:** Initiates visual and audible alarm when resistance to ground of positive or negative bus of battery is less than 5000 ohms.

2. **Battery compartment smoke/high-temperature detector** initiates a visual and audible alarm when smoke or a temperature greater than 75 degrees C occurs within the compartment.

3. **Annunciation of Alarms:** At UPS control panel.

**I. Additional Battery Monitoring**

1. Monitoring features and components include the following:

   a. Factory-wired sensing leads to cell and battery terminals and cell temperature sensors. Provide fuses as required for proper protection of conductors.

2. **Functional Performance:** Automatically measure and electronically record the following parameters on a routine schedule and during battery discharge events.
During discharge events record measurements timed to the nearest second. Include measurements of the following parameters:

a. Total battery voltage and ambient temperature;

b. Individual cell voltage, impedance, and temperature; Measure battery and cell voltages and time to the nearest second during battery discharging events such as utility outages;

c. Individual cell electrolyte levels.

J. Battery Cycle Warranty Monitoring

1. Description: Electronic device, acceptable to battery manufacturer as a basis for warranty action, for monitoring of charge-discharge cycle history of batteries covered by a life-cycle warranty.

2. Basic functional Performance: Automatically measures and records each discharge event, classifies it according to duration category, and totals discharges according to warranty criteria, displaying remaining warranted battery life on integral LCD.

3. Additional monitoring functions and features include the following:

a. Measuring and Recording: Total voltage at battery terminals, providing alarm for excursions outside the proper float voltage level.

b. Monitors: Ambient temperature at battery and initiates an alarm if temperature deviates from normally acceptable range.

c. Keypad on Device Front Panel: Provides access to monitored data using front panel display.

d. Alarm Contacts: Arranged to provide local alarm for abnormal temperature, abnormal battery voltage, or temperature.

e. Memory: Device stores recorded data in nonvolatile electronic memory.

f. RS-232 Port: Permits downloading data to a portable personal computer.

g. Modem: Makes measurements and recorded data accessible to remote personal computer via telephone line. Computer is not specified in this Section.

2.04 SOURCE QUALITY CONTROL

A. Factory test complete UPS, including battery, before shipment. Include the following tests:

1. Functional test and demonstration of all functions, controls, indicators, sensors, and protective devices.

2. Full-load test.


4. Overload test.

5. Power failure test.
B. Observation of Test: Give 14 days advance notice of test and provide opportunity for Resident Engineer to observe tests.

C. Report test results. Include the following data:

1. Description of input source and output loads used. Describe actions required to simulate source load variation and various operating conditions and malfunctions.

2. List of indications, parameter values, and system responses considered satisfactory for each test action. Include tabulation of actual observations during test.

D. List of instruments and equipment used in factory tests.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Examine elements and surfaces to receive equipment for compliance with installation tolerances and other conditions affecting performance, including, but not limited to, ambient temperature, cooling air circulation, contaminants and disassembly and maintenance space.

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

3.02 INSTALLATION

A. Install system components on 4-inch (nominal) high concrete bases. Cast-in-place concrete, reinforcing, and formwork are specified in Division 03, Concrete.

B. Maintain minimum clearances and workspace at equipment according to manufacture’s written instructions and NFPA 70.

C. Connections: Interconnect system components. Make connections to supply and load circuits according to manufacturer’s wiring diagrams, unless otherwise indicated.

D. GROUNDING

1. Comply with Section 26 05 26, Grounding and Bonding for Electrical Systems, for materials and installation requirements.

2. Comply with NFPA 70 for grounding and bonding requirements for Separately Derived Systems.

E. IDENTIFICATION

1. Identify components and wiring according to Section 26 05 53, Identification for Electrical Systems..

2. Equipment is labeled “Suitable for use on emergency systems” in accordance with NEC 700-3.

3. Instructional signs: Install approved legend where instructions or explanations are required for system of equipment operation.

F. BATTERY EQUALIZATION

1. Equalize charging of battery cells according to manufacturer’s written instructions. Record individual-cell voltages.
3.03  FIELD QUALITY CONTROL

A.  Manufacturer’s Field Service:  Engage the services of a factory-authorized service representative to supervise UPS installation, startup, and preliminary testing and adjustment and to participate in final tests, inspections, and adjustments.

B.  Electrical Tests and Inspections:  Perform tests and inspections according to manufacturer’s written instructions and as listed below to demonstrate condition and performance of each component of the UPS:

1.  Inspect interiors of enclosures, including the following:
   a.  Integrity of mechanical and electrical connections.
   b.  Component type and labeling verification.
   c.  Ratings of installed components.

2.  Test manual and automatic operational features and system protective and alarm functions.

3.  Test communication of status and alarms to remote monitoring equipment.

4.  Load the system using a variable-load bank to simulate kilovolt amperes, kilowatts, and power factor of loads for the unit’s rating.  Use instruments calibrated, within the previous 6 months according to National Institute of Standards and Technology (NIST) standards.
   a.  Simulate malfunctions to verify protective device operation.
   b.  Test duration of supply on emergency, low-battery voltage shutdown, and transfers and restoration due to normal source failure.
   c.  Test harmonic content of input and output current less than 25, 50, and 100 percent of rated loads.
   d.  Test output voltage under specified transient-load conditions.
   e.  Test efficiency at 50, 75, and 100 percent rated loads.
   f.  Test remote status and alarm panel functions.
   g.  Test battery-monitoring system functions.
   h.  Test resistance to ground of battery negative pole.

C.  Seismic-restraint inspections include the following:

1.  Inspect type, size, quantity, arrangement, and proper installation of mounting or anchorage devices.

2.  Test mounting and anchorage devices.

3.  Verify batteries are properly mounted and secured to battery racks.

D.  Correct deficiencies until specified requirements are met.

E.  Record of Inspections:  Maintain and submit documentation of inspections, including references to manufacturers written instructions and inspection criteria.  Include results of inspections.
3.04 CONSTRUCTION

A. Sequence Of Operations

1. Automatic operation includes the following:

a. Normal Conditions: Supply the load with ac power flowing from the normal ac power input terminals, through the rectifier-charger and inverter, with the battery connected in parallel with the rectifier-charger output.

b. Abnormal Supply Conditions: If normal ac supply deviates from specified and adjustable voltage, voltage waveform, or frequency limits, the battery supplies energy to maintain constant, regulated inverter ac power output to the load without switching or disturbance.

c. If normal power fails, energy supplied by the battery through the inverter continues to supply-regulated ac power to the load without switching or disturbance.

d. When power is restored at the normal supply terminals of the system, controls automatically synchronize the inverter with the external source before transferring the load. The rectifier-charger then supplies power to the load through the inverter and simultaneously recharges the battery.

e. If battery becomes discharged and normal supply is available, the rectifier-charger charges the battery. On reaching full charge, the rectifier-charger automatically shifts to a float-charge mode.

f. If any element of the UPS system fails and power is available at the normal supply terminals of the system, the static bypass transfer switch switches the load to the normal ac supply circuit without disturbance or interruption of supply.

g. If a fault occurs in the system supplied by the UPS and current flows in excess of the overload rating of the UPS system, the static bypass transfer switch operates to bypass the fault current to the normal ac supply circuit for fault clearing.

h. When the fault has cleared, the static bypass transfer switch returns the load to the UPS system.

i. If battery is disconnected, the UPS continues to supply power to the load with no degradation of its regulation of voltage and frequency of the output bus.

2. Manual operation includes the following:

a. Turning the inverter off causes the load to be transferred by the static bypass transfer switch directly to the normal ac supply circuit without disturbance or interruption.

b. Turning the inverter on causes the static bypass transfer switch to transfer the load to the inverter.

3. Maintenance Bypass/Isolation Switch Operation: Switch is interlocked so it cannot be operated unless static bypass transfer switch is in the bypass mode. Device provides manual selection between the following three conditions without interrupting supply to the load during switching:
a. Full Isolation: Load is supplied, bypassing the UPS. Normal UPS AC input circuit, static bypass transfer switch, and UPS load terminals are completely disconnected from external circuits.

b. Maintenance Bypass: Load is supplied, bypassing the UPS. UPS ac supply terminals are energized to permit operational checking, but system load terminals are isolated from the load.

c. Normal: Normal UPS ac supply terminals are energized and the load is supplied through either the static bypass transfer switch and UPS rectifier-charger and inverter, or the battery and the inverter.

3.05 DEMONSTRATION

A. Engage a factory-authorized service representative to train Sound Transit maintenance personnel to adjust, operate, and maintain the UPS.

B. Train Sound Transit maintenance personnel in the procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining equipment.

C. Review data in maintenance manuals. Refer to Section 01 78 23, Operation and Maintenance Data.

D. Schedule training with Resident Engineer with at least 7 days advance notice.

E. Monitoring and Testing Schedule: Perform monitoring and testing in a single 10-day period.
   1. Schedule monitoring and testing activity with Resident Engineer. Provide at least 7 days advance notice.
   2. Schedule monitoring and testing after substantial Completion, when UPS in supplying power to its intended load.

F. Monitoring and Testing Instruments: Three-phase, recording power monitors. Instruments provide continuous simultaneous monitoring of electrical parameters at input terminals of the UPS and at input terminals of a load served by the UPS. Instruments would monitor, measure, and graph voltage current and frequency simultaneously and provide full-graphic recordings of the values of those parameters before and during power line disturbances that cause the values to deviate from normal beyond the adjustable threshold values. Instruments are capable of recording either on paper or on magnetic media and have a minimum accuracy of plus or minus 2 percent for electrical parameters. Parameters to be monitored include the following:
   2. Voltage: Phase to phase, phase to neutral, phase to ground, and neutral to ground.
   3. Frequency transients.
   4. Voltage swells and sags.
   5. Voltage impulses, phase-to-phase, phase-to-neutral, phase-to-ground, and neutral-to-ground.
   6. High-frequency noise.
   7. Radio-frequency interference.
8. THD of the above currents and voltages.

9. Harmonic content of currents and voltages above.

G. Monitoring and Testing Procedure:

1. Exploratory Period: For the first 2 days, make recordings at various circuit locations and with various parameter-threshold and sampling-interval settings. Make these preliminary measurements with the objective of identifying optimum UPS, power system, load, and instrumentation set-up conditions for subsequent test and monitoring operations.

2. Remainder of Test Period: Perform continuous monitoring of at least two circuit locations selected on the basis of data obtained during exploratory period.
   a. Set thresholds and sampling intervals for recording data at values selected to optimize data on performance of the UPS with respect to values specified in Part 2 of this Section, and to highlight any need to adjust, repair, or modify the UPS or any distribution system or load component that may influence its performance or that may require better power quality.
   b. Perform load and UPS power source switching and operate the UPS on generator power during portions of the test period.
   c. Operate the UPS and UPS loads in each mode of operation permitted by UPS controls and by the power distribution system design.
   d. Create and simulate unusual operating conditions, including outages, voltage swells and sags, and voltage, current, and frequency transients that can be performed using loads and devices available as part of the facility’s installed systems and equipment. Maintain normal operating loads in operation on system to maximum extent possible during tests.
   e. Make adjustments and repairs to UPS, distribution, and load equipment to correct deficiencies disclosed by monitoring and testing and repeat appropriate monitoring and testing to verify success of corrective action.

H. Correlation with Specified UPS Monitoring Functions: Obtain printout recordings of built-in monitoring functions specified for UPS and UPS components in this Section that are simultaneous with those made with portable instruments in this Article.

1. Provide the temporary use of an appropriate personal computer and printer equipped with required connections and software for recording and printing if such units are not available on-site.

2. Correlate printouts with recordings for monitoring performed according to this Article; resolve and report anomalies in and discrepancies between the two sets of records.

I. Documentation: Record test point and sensor locations, instrument settings, and circuit and load conditions for each monitoring summary and power disturbance recording. Correlate simultaneous recordings made on UPS input and load circuits.

J. Analysis of Recorded Data and Report: Review and analyze test observations and recorded data and submit a detailed written report. Include the following in final report:

1. Description of corrective actions performed during monitoring and survey work and their results;
2. Recommendations for further action to provide optimum performance by the UPS;

3. Copies of monitoring summary graphics and graphics illustrating harmonic content of significant voltages and currents;

4. Copies of graphics of power disturbance recordings that illustrate findings, conclusions, and recommendations;

5. Recommendations for operating, adjusting, or revising UPS controls;

6. Recommendation for alterations to the UPS installation;

7. Recommendation for adjusting or revising generator-set or automatic transfer switch installations or their controls;

8. Recommendations for power distribution system revisions;

9. Recommendations for adjusting or revising electrical loads, or their connections or controls.

K. Interim and Final Reports: Provide an interim report at the end of each test period and final comprehensive report at the end of the final test and analysis period.

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SECTION 26 42 50
TUNNEL CORROSION CONTROL AT STATIONS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes requirements for corrosion control monitoring systems and electrical continuity for tunnel structures in the station box.

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, Raceway and Boxes for Electrical Systems.

1.02 REFERENCES

A. NACE International (NACE)

1. NACE RP0187-2002 Design Considerations for Corrosion Control of Reinforcing Steel in Concrete

B. National Electrical Manufacturers Association (NEMA)

1. NEMA 250 Enclosures for Electrical Equipment (1000 Volts Maximum)

C. National Fire Protection Association (NFPA)

1. NFPA 70 National Electrical Code

D. Underwriter’s Laboratories (UL)

1. UL 50 Enclosures for Electrical Equipment

1.03 SUBMITTALS

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

1. Assembly and installation drawings. Coordinate submittal with requirements of Section 26 05 33, Raceway 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.

2. Work to be performed under the direct supervision of a NACE International Cathodic Protection Specialist.

3. 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 drawings or specified herein, but which are required to fully carry out the specified intent of the work, shall be provided

B. Wire and Terminations

1. Test Leads
   a. Type: Type XHHW-2 or RHH/RHW, unless otherwise indicated.
   b. Cables for electrically continuous reinforcing steel test leads shall be #4 AWG, stranded, copper. Two test leads are required at each test box.
   c. Terminations: Compression type ring tongue or spring spade terminals with insulated ferrules. Quick-connect terminations are not acceptable.

C. 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.

D. 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.

E. 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 Electrical Code and other applicable State, County, or City codes and regulations. Nothing in the drawings or specifications 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. Any 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.

3. Stray Current Collector System Bonding Jumpers: Provide 2kV insulated copper stranded cable bonding jumpers across construction joints to permit joint movement without damaging bonding jumpers and welds.

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. Reinforcing Steel
1. 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 Drawings. Transverse bonding bars shall be installed at each end of the slab, at intermediate locations not to exceed 500 feet and where shown on Drawings for bonding around obstacles.

G. Steel Collector Cable Connection
Install bond cables to the bare steel collector cables as shown on the Drawings at each interface between the electrically continuous reinforcing steel mat at the stations and the bare steel collector cable in the tunnel.

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 assure conformance with the specifications. Testing shall include adequacy of test stations and electrical continuity of the steel reinforcing mat and the connections between the steel reinforcing mat and the bare steel collector cable. Upon completion of the tests, a detailed written report shall be submitted describing any deficiencies detected. Deficiencies shall be corrected by the Contractor at his 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. Electrically Continuous Reinforcing Steel Mat Continuity Testing

1. Verify electrical continuity of the top layer reinforcing steel mat 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. Replace any portion of the collector reinforcing mat which does not meet the above criteria at no cost to Sound Transit.

E. Reinforcing Steel to Bare Steel Collector Cable Testing

1. Verify electrical continuity of the steel reinforcing collector mat to the bare steel collector cable by measuring the longitudinal resistance. Acceptable resistance is no more than 1.10 times the theoretical resistance of the connection.

2. Testing shall be performed before and after concrete installation.

3. Replace any portion found which does not meet the above criteria 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
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing and installing luminaries for exterior and interior use, mounting hardware, and lamps.

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

1.02 REFERENCES

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

1. American National Standards Institute (ANSI):
   a. ANSI C62.41 Surge Voltages in Low-Voltage Ac Power Circuits
   b. ANSI C78.380 Electric Lamps – High Intensity Discharge Lamps, Method of Designation
   c. ANSI C81.62 Lampholders for Electric Lamps
   d. ANSI C82.4 Ballasts for High-Intensity-Discharge and Low Pressure Sodium Lamps (Multiple-Supply Type)

   b. ASTM A 167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip
   c. ASTM A 366/A 366M Standard Specification for Commercial Steel (CS) Sheet, Carbon, (0.15 Maximum Percent) Cold-Rolled

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):
   a. NFPA 70 National Electrical Code
   c. 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 66260.200 (e) Toxic Characteristic Leaching Procedure (TCLP).

1.03 SUBMITTALS

A. Refer to Section 01 33 00, Submittal Procedures.

B. Luminaire Product Data 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. Include the following information and exhibits:

1. Include in the manual a cover, title page, and table of contents. Verify that the cover and title page identify the document, project, client, Contract name, number and date of issuance. Ensure that the table of contents provides, 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. Ensure manual contents are prepared by the authorized manufacturer's representative serving the project area and include 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. Ensure the manual includes 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. Provide photometric reports from an independent, certified testing laboratory for each luminaire type where required by the luminaire schedule.
5. Ensure the manual includes 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 submittals a list of manufacturer’s representatives (including mailing address, e-mail address, and telephone and fax numbers) identifying which luminaire types they represent.

7. Provide templates for mounting of light poles. Provide dimensions to locations of openings and parts interfacing with remote systems, such as pole bases, mounting hardware, auxiliary electrical equipment, and lamps.

8. Provide calculations indicating capability of light poles with luminaires installed to withstand wind load requirements. Proper selection of anchor bolts shall be included in the computation.

   C. Test Reports: Submit test reports of factory and field tests performed, in accordance with applicable referenced standards and specification requirements. Report test data on 8-1/2 by 11-inch sheets and certified by a nationally recognized independent testing laboratory.

   D. 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, 120 V ballast, and wired to an eight-foot power cord terminated with standard 120 V grounding cord cap.

1.04 DELIVERY, HANDLING, AND STORAGE

   A. Handle and transport products in a manner that prevents damage.

   B. Wrap and package products to avoid damage.

   C. 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.

   D. Store products in a clean, dry, and secure storage area pending installation.

1.05 EXTRA STOCK

   A. Lamps: 10 percent of quantity furnished, minimum of two of each size and type.
B. Lenses: 3 percent of quantity furnished, minimum of one of each size and type.

C. Ballasts: 3 percent of quantity furnished, minimum of one of each size and type.

1.06 WARRANTY

A. Ballasts: Provide manufacturer’s warranty for a period of not less than 5 years covering the full cost of a replacement ballast excluding labor.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Luminaires

1. Requirements:

a. Luminaires schedule catalog numbers 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. Verify luminaire voltages with Contract Drawings.

b. Provide luminaires, complete and ready for service. 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.

c. Mark luminaires clearly with manufacturer’s name and catalog number, voltage, acceptable lamp type, maximum wattage, and label for intended use.

d. Verify luminaires are UL listed for the location and application intended.

e. Verify luminaires containing lamps which require protective shielding are provided with tempered glass lens.

f. Verify luminaires are free of light leaks and designed to provide required ventilation for electrical components. Verify luminaires control temperature of lamps such that lamps reach full light output under installed environmental conditions.

g. For adjustable luminaires, provide positive locking devices to fix aiming angle. Verify luminaires are capable of being relamped without affecting aiming angle.

h. Provide safety devices for removable luminaire elements (IE 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.
2. Materials:
   a. 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.
   b. 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.
   c. Verify the acrylic for lenses and diffusers is manufactured from virgin-acrylic extrusion or injection molding pellets.
   d. Verify the polycarbonate for lenses is manufactured from high temperature resin designed for use with HID lamps.
   e. Verify the glass for lenses is tempered borosilicate pressed or spun glass, minimum 0.13 inch thick.
   f. Verify stainless steel is Type 304 conforming to ASTM A 167.

3. Finishes:
   a. 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.
   b. Do not start finishing operations until fabrication and forming operations have been completed.
   c. 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.
   d. Ensure Aluminum to be anodized is given a Class 1 anodic coating.
   e. Anodize aluminum in accordance with procedures established by alloy manufacturer to achieve color within specified range.
   f. Apply a clear organic protective coating to exposed aluminum surfaces that may experience prolonged contact with caustic material such as concrete or plaster.
   g. Verify that the minimum cleaning of metal before painting is 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.
   h. Verify interior luminaires with surfaces not exceeding 150 degrees F are statically charged and painted two coats minimum of acrylic gloss enamel to a minimum total dry film thickness (DFT) of 2.5 mils.
   i. Verify interior luminaires with surfaces exceeding a temperature of 150 degrees F, but not exceeding 300 degrees F, are statically charged and painted with silicone-alkyd enamel, two coats minimum to a total DFT of 2.5 mils.
j. For exterior or corrosive locations, finish luminaires and accessories with weather-resistant enamel using proper primers or bondedorized epoxy over galvanized surfaces. Ensure the entire luminaire assembly is corrosion-resistant under the installed service conditions.

k. Provide luminaires specified to be painted with one coat of epoxy-polyamide at a minimum DFT of 2 mils and one coat of aliphatic urethane to a minimum DFT of 2 mils. Ensure interior reflective surfaces be painted as are interior luminaires.

l. For finish luminaires specified to be porcelain enameled, or painted luminaires with reflectors specified to be porcelain enameled, ensure they receive porcelain-enamel coating in accordance with the requirements of PEI-1001.

m. Finish reflective surfaces that are not specified to be specular to be gloss white, guaranteed nonyellowing, with a reflectance rating of not less than 88 percent.

n. Provide galvanized coating, where indicated, hot-dip galvanized according to ASTM A 123/A 123M. 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 mil 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.

B. 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. Ensure retention devices do not deform the cone. Install trim to be 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. Ensure reflector cones are of uniform gage, not less than 0.032-inch, high purity aluminum alloy, free of spin marks or other defects.

e. Ensure reflectors have an Alzak or equal finish. Refer to luminaire schedule for cone color and specular or diffuse finish requirements. For luminaires using compact fluorescent lamps, provide additional finish equivalent to Color-Chek, which will eliminate iridescence.

2. Fresnel Lens and Door Assembly:

a. Use 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. Use 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.

C. 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 W, 600 V, or as indicated. Ensure lampholders hold lamps securely and withstand normal vibration and maintenance handling.

b. 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.

c. 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.

d. Provide incandescent and high intensity discharge lampholders of glazed porcelain body with nonferrous metal components of heavy duty design, vibration resistant.

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 kV pulse rated, 1.5 kW, 600 V, for metal halide and high-pressure sodium lamps 250 W and up to and including 1 kW.

e. Provide fluorescent lampholders of white urea, spring loaded with silver-plated contacts of the pedestal or button type.

1) Supply rapid start lamps which use medium bipin spring-loaded lampholders of the tombstone or butt configuration.

2) Supply miniature fluorescent preheat and circline lamps which use special lampholders as recommended by the individual lamp manufacturer.

2. Ballasts:

a. Ensure ballasts are 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 ANSI C82.4.

c. Install pulse start metal halide lamps to be operated by a linear reactor type ballast with ignitor or a constant wattage auto-transformer (CWA) type ballast to provide the required nominal 4kV (3kV to 5kV) pulse to start. Electronic ballasts are acceptable where the lamp/ballast combination has been approved by the lamp manufacturer.

d. Install high intensity discharge luminaires to have a non-time delay automatically switched quartz standby light where indicated on the Contract Drawings. Ensure the quartz light turn on when power is restored and turn off when the HID lamp restrikes.

e. Install high pressure sodium lamps, 250 W size and larger, to be operated by a constant wattage autotransformer (CWA) type ballast.

f. Ensure ballast for fluorescent lamps matches the characteristics of the lamps, and meets the following requirements:
   1) Operate lamps at a frequency of 20 kHz 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.

g. Ensure Ballasts for T5 fluorescent lamps be Programmed Start, electronic type suitable for high-output T5 fluorescent lamps.

h. Supply dimming ballasts, where required, of a type appropriate for the dimming controller and consistent with product listing. Ensure total harmonic distortion not exceed 20 percent at any point within the dimming range.
i. Electromagnetic Ballasts: Comply with ANSI C 82.1; energy saving, high-power factor, Class P, and having automatic-reset thermal protection.

1) Ballast Manufacturer Certification: Indicated by label.

j. Single Ballasts for Multiple Lighting Fixtures: Factory-wired with ballast arrangements and bundled extension wiring to suit final installation conditions without modification or rewiring in the field.

k. Ballasts for Low-Temperature Environments:

1) Temperatures 0 Deg F and Higher: Electronic or electromagnetic type rated for 0 Deg F starting and operating temperature with indicated lamp types.

l. Ballasts for Compact Fluorescent Lamps: Electronic programmed rapid-start type, complying with ANSI C 82.11, designed for type and quantity of lamps indicated. Ballast shall be designed for full light output unless dimmer or bi-level control is indicated.

1) Lamp end-of-life detection and shutdown circuit.
2) Automatic lamp starting after lamp replacement
3) Sound Rating: A.
4) Total Harmonic Distortion Rating: Less than 20 percent.
5) Transient Voltage Protection: IEEE C 62.41, Category A, or better.
6) Operating Frequency: 20 kHz, or higher.
7) Lamp Current Crest Factor: 1.7, or less.
8) BF: 0.95 or higher, unless otherwise indicated.
9) Power Factor: .098, or higher.
10) Interference: Comply with 47 CFR, Chapter 1, Part 18, Subpart C, for limitations on electromagnetic and radio-frequency interference for non-consumer equipment.
11) Ballast Case Temperature: 75 Deg C, maximum.

m. Ballasts for HID Lamps:

1) Electromagnetic Ballast for Metal-Halide Lamps: Comply with ANSI C 82.4 and UL 1029. Include the following features, unless otherwise indicated:

a) Ballast Circuit: Constant-wattage autotransformer or regulating high-power-factor type.

b) Minimum Starting Temperature: Minus 22 Deg F for single-lamp ballasts.

c) Normal Ambient Operating Temperature: 104 Deg F.
d) Open-circuit operation that will not reduce average life.

e) Low-Noise Ballasts: Manufacturers’ standard epoxy-encapsulated models designed to minimize audible fixture noise.

2) Electronic Ballast for Metal-Halide Lamps: Include the following features, unless otherwise indicated.

a) Lamp end-of-life detection and shutdown circuit.

b) Sound Rating: A.

c) Total Harmonic Distortion Rating: Less than 15 percent.

d) Transient Voltage Protection: IEEE C 62.41, Category A, or better.

e) Lamp Current Crest Factor: 1.5, or less.

f) Power Factor: .90, or higher.

g) Interference: Comply with 47 CFR, Chapter 1, Part 18, Subpart C, for limitations on electromagnetic and radio-frequency interference for non-consumer equipment.

h) Protection: Class P thermal cutout.

3) High-Pressure Sodium Ballasts: Electromagnetic type, with solid-state igniter/starter. Igniter/starter shall have an average life in pulsing mode of 10,000 hours at an igniter/starter-case temperature of 90 Deg C.

a) Minimum Starting Temperature: Minus 40 Deg F.

b) Open-circuit operation shall not reduce average lamp life.

3. Luminaire Wiring:

a. Provide luminaire wires of 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. Provide wiring within the luminaries that complies with the National Electrical Code.

c. 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.
d. Ensure flexible cord wiring between luminaire components or to electrical receptacle but not in wireways has a minimum temperature rating of 105 degrees C.

e. Fit Cords with proper strain reliefs and watertight entries where used for damp or wet location luminaires.

f. 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 an additional two-lamp ballast for the center lamp in both luminaires.

g. 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.

h. 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.

D. 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 A 366/A 366M sheet steel, zinc-coated after fabrication, or finished extruded aluminum.

4. Verify 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. Verify that junction boxes suitable for the intended location and wiring requirements are provided with four 3/4-inch threaded and plugged conduit entries.
E. Luminaire Mounting Hardware:

1. Provide luminaires with brackets, straps, canopies and stems, and miscellaneous hardware suitable for the mounting method specified. Ensure pendant mounted luminaires have seismic resistant swivel mountings.

2. When exposed to public view, fabricate and finish hardware in material matching the luminaire body.

3. Supply canopies, holders, and similar parts that are drawn or spun in one piece with a minimum 0.026-inch finished thickness.

4. Verify tubing used for stems is seamless drawn with a minimum of 1/16-inch wall thickness of size and length as indicated. Ensure stems are provided for pendant mounted luminaires of length as required for the specified mounting height with swivel hangers or ball aligners as required.

F. Lamps:

1. Requirements: Provide each luminaire with the number, type, and wattage of lamps required as indicated. Provide 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 all lamps of each type are provided by a single manufacturer.

2. Compact Fluorescent Lamps: Configure as required by luminaire manufacturer. Ensure lamps have a rated minimum average life of 10,000 hours, minimum 82 Color Rendering Index (CRI) and minimum 2700 degrees Correlated Color Temperature (CCT).

3. Fluorescent Lamps:
   a. Energy-efficient T8, rapid start fluorescent lamp rated 265 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).
   b. High-output T5, programmed start fluorescent lamp, wattage rating as indicated.
   c. Ensure lamps have a rated minimum average life of 20,000 hours, minimum 78 Color Rendering Index (CRI), and minimum 3500 degrees K Correlated Color Temperature (CCT).

4. Metal Halide Lamps: Clear or coated as indicated, suitable for all operating positions. Ensure Photometric characteristics provide maximum luminous output while operating in the horizontal position with color temperature of 3700 degrees K and CRI of 70.

5. 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).
6. **Light-Emitting Diode (LED) Exit Signs:** 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.

**G. Steel Poles:**

1. **Poles:** Comply with ASTM A 500, Grade B, carbon steel with a minimum yield of 46,000 psig; 1-piece construction up to 40 feet in height with access handhole in pole wall.
   a. **Shape:** Round tapered and square straight.
   b. **Mounting Provisions:** Butt flange for bolted mounting on foundation.

2. **Steel Mast Arms:** Single-arm and two-luminaire bracket type, continuously welded to pole attachment plate. Material and finish same as pole.

3. **Brackets for Luminaires:** Detachable, cantilever, without underbrace.
   a. **Adapter fitting welded to pole and bracket, then bolted together with stainless-steel bolts.**
   b. **Cross Section:** Tapered oval, with straight tubular end section to accommodate luminaire.
   c. **Match pole materials and finish.**

4. **Pole-Top Tenons:** Fabricated to support luminaire or luminaires and brackets indicated, and securely fastened to pole top.

5. **Steps:** Fixed steel, with nonslip treads, positioned for 15-inch vertical spacing, alternating on opposite sides of pole; first step at elevation 10 feet above finished grade.

6. **Intermediate Handhole and Cable Support:** Weathertight, 3-by-5-inch handhole located at midpoint of pole with cover for access to internal welded attachment lug for electric cable support grip.

7. **Grounding and Bonding Lugs:** Welded 1/2-inch threaded lug, complying with requirements in Division 16, Section “Grounding and Bonding”, listed for attaching grounding and bonding conductors of type and size listed in that Section, and accessible through handhole.

8. **Cable Support Grip:** Wire mesh type with rotating attachment eye, sized for diameter of cable and rated for a minimum load equal to weight of supported cable times a 5.0 safety factor.

9. **Platform for Lamp and Ballast Servicing:** Factory-fabricated of steel with finish matching that of pole.

10. **Prime-Coat Finish:** Manufacturer’s standard prime coat finish ready for field painting.

11. **Galvanized Finish:** After fabrication, hot-dip galvanize complying with ASTM A 123/A 123M.
12. **Factory-Painted Finish:** Comply with NAAMM’s “Metal Finishes Manual for Architectural and Metal Products” for recommendations for applying and designating finishes.

   a. **Surface Preparation:** Clean surfaces to comply with SSPC-SP 1, “Solvent Cleaning”, to remove dirt, oil, grease, and other contaminants that could impair paint bond. Grind welds and polish surfaces to a smooth, even finish. Remove mill scale and rust, if present, from uncoated steel, complying with SSPC-SP 5/NACE No. 1, “White Metal Blast Cleaning”, or SSPC-SP 8, “Pickling”.

   b. **Interior Surfaces of Pole:** One coat of bituminous paint, or otherwise treat for equal corrosion protection.

   c. **Exterior Surfaces:** Manufacturer’s standard finish consisting of one or more coats of primer and two finish coats of high-gloss, high-build polyurethane enamel.

      1) **Color:** As specified in the lighting schedule on plans.

**H. Pole Accessories:**

1. **Base Covers:** Manufacturers’ standard metal units, arranged to cover pole’s mounting bolts and nuts. Finish same as pole.

**2.02 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.

**2.03 RETROFIT KITS FOR FLUORESCENT LIGHTING FIXTURES**

**A.** Comply with UL 1598 listing requirements.

1. **Reflector Kit:** UL 1598, Type I. Suitable for two- to four-lamp, surface-mounted or recessed lighting fixtures by improving reflectivity of fixture surfaces.

2. **Ballast and Lamp Change Kit:** UL 1598, Type II. Suitable for changing existing ballast, lamps, and sockets.

**2.04 REQUIREMENTS FOR INDIVIDUAL LIGHTING FIXTURES**

**A.** All interior luminaires individually are specified in the Lighting Schedule on plans.
PART 3 - EXECUTION

3.01 INSTALLATION

A. 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, 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.

5. 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.

6. For suspended luminaires, provide the indicated mounting height clearances
between the bottoms of the luminaires and the finished floors.

7. 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.

8. 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.

9. 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.
10. Provide pendant luminaires with stem swivel hangers to ensure a plumb installation with a minimum 45-degree swing from horizontal in all directions. Where 45-degree movement of luminaire is not possible due to field conditions, provide, in addition to above, cross bracing of aircraft cable to restrict movement in direction of potential contact. Use tubing that is not less than 3/16-inch diameter. Ensure that motion of swivels or hinged joints does not cause sharp bends in conductors or damage to insulation. For heavy pendant-mounted luminaires, where support is to be independent of the outlet box, provide stem swivel hangers with luminaire studs.

11. Install pole-mounted luminaires in accordance with manufacturer's installation instructions.

12. Provide required lamps in each luminaire as soon as luminaires are properly installed.

13. Refer to architectural reflected ceiling drawings to coordinate luminaire locations with mechanical and fire protection equipment. Notify Resident Engineer of all conflicts.


15. Enclose luminaires located in recessed ceilings with a fire-resistive rating of one-hour or more in an approved fire-resistive rated box equal to that of the ceiling.

16. Ensure fluorescent lamps operating with dimming ballasts are operated at full light output for 100 hours prior to dimming.

17. Adjust variable-position lampholders to proper lamp position prior to luminaire installation.

18. For pendant-mounted luminaires, mounting height is from finished ceiling to top of luminaire.

19. Provide 72-inch flexible conduit whip for recessed luminaires located in suspended ceilings.

B. Ballasts:

C. 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.

D. 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.

E. Poles:

1. Align pole foundations and poles for optimum directional alignment of luminaires and their mounting provisions on the pole.
2. Clearances: Maintain the following minimum horizontal distances of poles from surface and underground features, unless otherwise indicated on Drawings.
   a. Fire Hydrants and Storm Drainage Piping: 60 inches.
   c. Trees: 15 feet.

3. Concrete Pole Foundations: Set anchor bolts according to anchor bolt templates furnished by pole manufacturer. Concrete materials, installation, and finishing requirements are specified in Division 3, Section “Cast-in-Place Concrete”.

4. Foundation-Mounted Poles: Mount pole with leveling nuts, and tighten top nuts to torque level recommended by pole manufacturer.
   a. Use anchor bolts and nuts selected to resist seismic forces defined for the application and approved by manufacturer.
   b. Grout void between pole base and foundation. Use non-shrink or expanding concrete grout firmly packed to fill space.
   c. Install base covers, unless otherwise indicated.
   d. Use a short piece of 1/2-inch diameter pipe to make a drain hole through grout. Arrange to drain condensation from interior of pole.

5. Poles and Pole Foundations Set in Concrete Paved Areas: Install poles with minimum of 6-inch wide, unpaved gap between the pole or pole foundation and the edge of adjacent concrete slab. Fill unpaved ring to a level 1-inch below top of concrete slab.

6. Raise and set poles using web fabric slings (not chain or cable).

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.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, and installing a fully addressable fire alarm and smoke detection system and voice evacuation system.

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 26, Grounding and Bonding for Electrical Systems.

1.02 REFERENCES

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

1. National Fire Protection Association (NFPA):
   a. NFPA 70 National Electrical Code

2. International Fire Code Institute (IFC):
   a. Uniform Fire Code (UFC)
   b. International Association of Plumbing and Mechanical Officials (IAPMO)
   c. Uniform Mechanical Code (UMC)

   a. 42 U.S.C. 12181 Americans with Disabilities Act of 1990 (Title III) (ADA)

4. Seattle Fire Department

5. Seattle Fire Code

6. Seattle Department of Design, Construction and Land Use

7. Seattle Electrical Code

8. Seattle Mechanical Code
1.03 SYSTEM DESCRIPTION

A. The system shall provide addressable alarm points including the following:

1. Smoke Spot Detection
2. Heat Spot Detection
3. Water Flow
4. Pressure Switch
5. Tamper Switches
6. Preaction sprinkler system
7. Manual Pull Stations
8. Reflective Beam Detectors
9. Linear Heat Detectors

B. Analog Thermal detectors:

1. Shall be provided to detect a high temperature condition in the indicated areas.
2. Thermal detectors shall be located in accordance with guidelines in NFPA 72 or manufacturers UL (or FM, if applicable) listed spacing.
3. Thermal detectors shall not be installed immediately above heating appliances.
4. Thermal detectors, rated as required, shall be provided to detect a high temperature condition in ceiling and roof structure cavities as required by code authority.

C. Photoelectric detectors shall be provided to detect fire conditions in the required areas. Detectors shall be located in accordance with the guidelines of NFPA 72.

D. Reflective Beam detectors and linear heat detectors shall be provided to detect fire conditions in the chamber area. Detectors shall be located in accordance with the guidelines of NFPA 72.

E. A rechargeable battery supply shall be provided to automatically operate the entire fire detection and alarm system, including detectors, control panel, remote fire annunciator, alarm sounding devices, and auxiliary control equipment (unless otherwise specified herein) in the event of a loss of primary power.

F. Audible and visible evacuation alarms shall be provided throughout the station.

G. An Ethernet port shall be provided on the Fire Alarm control Panel (FACP) to report all alarms and fire system status to the Central Control System through the Building Management System (BMS).

H. The fire alarm system shall be compatible with the existing fire alarm subpanel installed in the tunnel. A fiber optic communication port shall be provided for connection of an existing subpanel installed in a previous contract. The existing panel is located in the tunnel and shall be connected to the station FACP to allow all alarms and system status to be reported to the Central control system through the BMS.
I. Fire system status provided by the interface port shall include all FACP status, alarm and control information including:

1. Individual detector alarms
2. Individual detector malfunction
3. Zone Alarms
4. Manual alarm stations
5. Flow switches
6. Tamper switches
7. Deluge system actions
8. Pre-action systems
9. Clean Agent systems
10. Elevator recall and/or shutdown
11. FACP real time clock
12. FACP system trouble
13. Fire Doors
14. Voice Evacuation System Trouble

J. Provide documentation of all status items available. The intent is to fully identify each status item to other contractors for system interoperation and graphical display building.

1.04 SUBMITTALS

A. Refer to Section 01 33 00, Submittals, for submittal requirements and procedures.

B. Shop Drawings:

1. Drawings shall be drawn on 24-inch by 36-inch erasable mylar or approved. Layout Plan Drawings, Interconnect Drawings, and Wiring Diagrams must have Seattle Fire Department approval prior to submitting to the Resident Engineer. Submitted Drawings shall have Seattle Fire Department approval marked thereon.

2. Provide a general layout of the complete system including equipment arrangement. It shall be the responsibility of the fire alarm installer to verify dimensions and ensure compatibility all other systems interfacing with the fire alarm system.

3. Identify on the Drawings; raceway and conductor sizes and types with number of conductors in each conduit. Provide each raceway and device with a unique alphanumeric identification.

4. Indicate on the point to point wiring diagrams, interconnecting wiring within the panel between modules, and connecting wiring to the field device terminals.
C. Interconnect Drawings: Show only external connections between equipment and devices. All wires shall be identified with alphanumeric designators and all termination points shall show the correct terminal identification.

D. Wiring Diagrams: Show the general physical arrangement of the component parts of the equipment and the connection of all internal wiring. All components, wires, terminal strips, and terminals shall be identified with alphanumeric designators.

E. Equipment Mounting Details: Show the mounting location for all floor and wall mounted equipment including distance from floor and column lines, and fabrication details for all special mounting brackets. Details shall also provide any special installation instructions. These details may be included on the Layout Plan Drawings if space allows.

F. Layout Plan Drawings: Show every device provided under this Section in its relative spatial location. Sections and elevations shall be utilized as necessary to accurately describe the installed location of all devices.

G. System Calculations:
   1. Provide voltage drop calculations indicating the system ability to furnish power at a minimum of 90 percent of nameplate listing in a standby power condition with all devices in alarm utilizing the proposed wire type and size. Demonstrate that no single wire run between a circuit and its most remote device exceeds the manufacturer’s recommendations for wire length, circuit resistance, or circuit wire to wire and wire to ground capacity.

H. Battery Calculations: Itemize battery loads under standby and alarm conditions. Auxiliary power supplies and transponder battery calculations shall demonstrate the ability of the batteries to supply the required secondary power for a period of 24 hours (or local code requirements) with no external power applied and furnish power for worst case alarm signaling for 5 minutes at the end of this period with all devices in alarm and all device LED’s lighted. Battery sizing shall be at a factor of 1.5 times the results of this mathematical requirement to account for battery aging between replacements and for system modifications and expansions. Complete the Fire Alarm Emergency Power Calculation form in NFPA 72 appendix.

I. Voice Evacuation System Calculations: Provide predicted sound level calculations demonstrating that sound level and intelligibility criteria as defined in NFPA 72 Appendix E are met by the proposed speaker system. Calculations shall demonstrate that wire size and length meet manufacturer’s recommendations.

J. Equipment Data Sheets:
   1. Show the color, configuration and dimensions of the equipment or device described.
   2. Provide technical Contract Specifications, such as operating voltage, operating temperature and humidity limitations, mounting and wiring information and a description of the function and operation of the device.

K. Recommended Spare Parts List:
   1. Submit a listing of all devices and components recommended for Sound Transit purchase as spare parts to support the system. The list shall include recommended quantities for all items.
   2. Provide unit price list valid for 90 days after submittal.
3. Scheduled Testing: The vendor shall include step-by-step procedures and allowances for performance testing every fire alarm device and system output to demonstrate functionality in accordance with specification requirements and Seattle Fire Department requirements.

L. Operation and Maintenance Manuals: Manuals shall contain the following minimum information:

1. Complete Operating Instructions.
2. Preventative Maintenance Instructions.
3. Catalog Sheets on all Devices and Equipment.
4. Manufacturers Operation and Maintenance Instructions.

M. Record Drawings: At the completion of the installation, provide record drawings to reflect the accurate as-built condition. Working plans shall show actual, accurate locations of devices, and actual routing of conduit and location of end of line devices. The installer shall provide updated as-builts on CADD and two full-size prints of the Record Drawings.

N. Acceptance Test Procedure (ATP):

1. Submit for approval, prior to testing, an ATP meeting the requirements of this Section.
2. Submit, for system record, all required data as compiled during installation and testing upon completion of the ATP tests. These data shall be loose leaf bound and labeled as system acceptance testing information.
3. Submit, for system record, a completed "Fire Alarm System Certification and Description" as included in NFPA 72.

1.05 QUALITY ASSURANCE

A. Regulatory Requirements

1. "Component Listing: Fire detection and alarm components furnished under this Section shall be UL listed, listed in the Fire Equipment List or FM, approved for fire signaling or fire suppression use. Accessory equipment shall be manufactured with UL listed components.

2. Conform to the requirements of NFPA 101 and NFPA 72.

3. Conform to applicable local regulations. Design and installation shall meet the requirements of the Seattle Fire Department.

B. Qualifications

1. Manufacturer: Company specializing in smoke detection and fire alarm systems with 5 years experience.

2. Installer: Company specializing in smoke detection and fire alarm systems with 5 years documented experience and certified by the manufacturer as a fire alarm installing contractor.

   a. Contract shall ensure that Installer evaluates and supplements the design shown in the Contract Drawings as required for proper detection
and alarm annunciation consistent with the characteristics of the products he proposes to incorporate into the system.

b. Contract shall ensure that Installer prepares a design that, in addition to the minimum requirement shown, includes all additional design equipment and installation necessary to obtain Seattle Fire Department acceptance.

3. Warranty: All manufacturer warranties shall be passed on to Sound Transit. Installation shall be warranted for a minimum period of two years after system acceptance.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. Edwards Systems Technology
B. Notifier
C. Honeywell
D. Simplex Systems
E. Siemens
F. GE Security
G. Approved Equal

2.02 MATERIALS

A. General Requirements

1. Equipment shall be new and marketed by a single manufacturer. The system shall include equipment, software, firmware, raceways, and wiring as required to provide a complete and operating system in full compliance with these Contract Specifications, Contract Drawings and requirements of the Seattle Fire Department.

B. Fire-Alarm Control Panel (FACP)

1. General Requirements for Fire-Alarm Control Panel:

   a. Field-programmable, microprocessor-based, modular, power-limited design with electronic modules, complying with UL 864 and listed and labeled by an NRTL. Panel shall be listed for fire alarm and releasing service.

      1) System software and programs shall be held in flash electrically erasable programmable read-only memory (EEPROM), retaining the information through failure of primary and secondary power supplies.

      2) Include a real-time clock for time annotation of events on the event recorder and printer.
3) Addressable initiation devices that communicate device identity and status.
   a) Smoke sensors shall additionally communicate sensitivity setting and allow for adjustment of sensitivity at fire-alarm control unit.
   b) Temperature sensors shall additionally test for and communicate the sensitivity range of the device.

4) Addressable control circuits for operation of mechanical equipment.

b. Alphanumeric Display and System Controls: Arranged for interface between human operator at fire-alarm control panel and addressable system components including annunciation and supervision. Display alarm, supervisory, and component status messages and the programming and control menu.
   1) Annunciator and Display: Liquid-crystal type, 2 line(s) of 40 characters, minimum.
   2) Keypad: Arranged to permit entry and execution of programming, display, and control commands and to indicate control commands to be entered into the system for control of smoke-detector sensitivity and other parameters.

c. Circuits:
   1) Initiating Device, Notification Appliance, and Signaling Line Circuits: NFPA 72, Class A.
   2) Initiating Device Circuits: Style C.
   3) Notification Appliance Circuits: Style Y.
   4) Signaling Line Circuits: Style 4.
   5) Install no more than 50 addressable devices on each signaling line circuit.
   6) Serial Interfaces: Two RS-232 ports for printers.

d. Notification Appliance Circuit: Circuits for strobe and speaker operation. Audible alarms shall include temporal warning tones. Notification Appliance circuits shall interface with the Voice Evacuation system panel.

e. Elevator Recall:
   1) Smoke detectors at the following locations shall initiate automatic elevator recall.
      a) Elevator lobby detectors except the lobby detector on the designated floor.
      b) Smoke detector in elevator machine room.
c) Smoke detector at top of elevator shaft.

2) Elevator lobby detectors located on the designated recall floors shall be programmed to move the cars to the alternate recall floor.

3) Water-flow alarm connected to sprinkler in an elevator shaft and elevator machine room shall shut down elevators associated with the location without time delay.

   a) Water-flow switch associated with the sprinkler in the elevator pit may have a delay to allow elevators to move to the designated floor.

f. Door Controls: Door hold-open devices that are controlled by smoke detectors at doors in smoke barrier walls shall be connected to fire-alarm system.

g. Remote Smoke-Detector Sensitivity Adjustment: Controls shall select specific addressable smoke detectors for adjustment, display their current status and sensitivity settings, and change those settings. Allow controls to be used to program repetitive, time-scheduled, and automated changes in sensitivity of specific detector groups. Record sensitivity adjustments and sensitivity-adjustment schedule changes in system memory, and print out the final adjusted values on system printer.


i. Printout of Events: On receipt of signal, print alarm, supervisory, and trouble events. Identify zone, device, and function. Include type of signal (alarm, supervisory, or trouble) and date and time of occurrence. Differentiate alarm signals from all other printed indications. Also print system reset event, including same information for device, location, date, and time. Commands initiate the printing of a list of existing alarm, supervisory, and trouble conditions in the system and a historical log of events.

j. Instructions: Computer printout or typewritten instruction card mounted behind a plastic or glass cover in a stainless-steel or aluminum frame. Include interpretation and describe appropriate response for displays and signals. Briefly describe the functional operation of the system under normal, alarm, and trouble conditions.

C. System Power Supply

1. Input Power: 120 volts ac. from UPS.

2. Secondary Power Supply:

   a. Provide sealed gelled-electrolyte batteries as the secondary power supply for the fire alarm control panel and each system transponder. The battery supply shall be sized to operate the system in a supervisory mode for a period of 24 hours with no primary power applied and at the end of that period operate its alarm mode for a period of five minutes. Batteries shall be sized at 30 percent above the calculated size to
compensate for deterioration and aging during the battery life cycle. Batteries shall be housed in the control cabinet or a separate cabinet with adequate cell separation to prevent accidental discharge. If housed in a separate cabinet, a fuse block shall be provided within the battery cabinet.

b. Provide battery-charging circuitry for each standby battery bank in the system low voltage power supply or as a separate circuit. The charger shall be automatic in design, adjusting the charge rate to the condition of the batteries. Charger shall be housed in the main fire alarm control panel or the battery cabinet. The charger shall be capable of charging the batteries from 75 percent of full charge to 100 percent of full charge within 24 hours.

D. Manual Fire-Alarm Boxes

1. General Requirements for Manual Fire-Alarm Boxes: Comply with UL 38 and NFPA 72. Boxes shall be finished in red with molded, raised-letter operating instructions in contrasting color; shall show visible indication of operation; and shall be mounted on recessed outlet box. If indicated as surface mounted, provide manufacturer's surface back box.

a. Double-action mechanism requiring two actions to initiate an alarm, breaking-glass or plastic-rod type; with integral addressable module arranged to communicate manual-station status (normal, alarm, or trouble) to fire-alarm control panel.

b. Station Reset: Key- or wrench-operated switch.

E. Analog Addressable Heat Detectors

1. Rate compensated type, rated at 135 degrees F. Detectors shall be constructed to compensate for the thermal inertia inherent in detectors due to the thermal mass, and alarm at the set point. Detector bases shall be of the twist-lock style and shall be provided with an indicating light to verify operation, which shall latch on in an alarm condition. Removal of the detector from its base shall cause a system trouble signal. Devices utilizing pins, jumpers, or staples are not acceptable.

F. Analog Addressable Smoke Detectors, Photoelectric

1. Light refraction technology smoke detectors shall have a high rejection of false signals caused by electrical noise and electrical transients and shall be capable of being checked for sensitivity without being removed from its twist-lock base. The reading of the detector sensitivity shall yield a discrete electrical value for logging and tracking of status to determine the maintenance and cleaning requirements. The detector shall be capable of being readily disassembled to gain access to the detection chamber for cleaning and maintenance. Detectors shall be used for open area protective coverage and shall be insensitive to air velocity.

2. Detector bases are to be low-profile, twist-lock. Bases shall be capable of installation on a 4-inch square or octagonal electrical outlet box. The detector base shall be equipped with an indicating LED that shall flash to indicate system communications and shall change state to a steady “on” when the detector reaches the selected threshold for alarm and communicates that alarm to the system. Removal of the detector from the base shall cause a system trouble
condition with and display a distinctive trouble code on the control panel display indicating the zone of the trouble condition.

G. Analog Addressable Duct Detectors

1. Air Duct Smoke Detectors:
   a. Sampling photoelectric or ionization type for sensing of products of combustion within the air stream of ducted fan systems. The devices shall include necessary sampling tube extensions and sensitivity adjustments for detection of products of combustion across the width of the duct.
   b. The device shall actuate upon nominal 2 percent light obscuration per foot. Visual indication of normal and alarm/trouble shall be incorporated into the exposed surface of the device. Two auxiliary contacts shall be provided for connection to mechanical control system.

2. Detectors shall be approved for use in environments as covered by FM, UL 268a, and UL 268. Detectors furnished shall be available in the following configurations to serve all possibilities:
   a. High Velocity: As listed for use in HVAC duct detection applications of air velocities of up to 1200 feet per minute.
   b. Low Velocity: As listed for use in HVAC duct detection applications of velocities between 500 and 4000 feet per minute.

3. Detector bases are to be low-profile, twist-lock type with screw clamp terminals and self wiping contacts. A security lock shall be installed in those areas where indicated on the Drawings as requiring tamper resistant installation. Bases shall be capable of installation on a 4-inch square or octagonal electrical outlet box. The detector base shall be equipped with an indicating LED that shall flash to indicate system communications and shall change state to a steady "on" when the detector reaches the selected threshold for alarm and communicates that alarm to the system. The specified LED functions shall indicate detector state whether the system is in the normal mode or the standby power mode. Removal of the detector from the base shall cause a system trouble condition with and display a distinctive trouble code on the control panel display indicating the zone of the trouble condition.

H. Reflective Beam Detectors

1. Single ended intelligent reflected beam smoke detectors with integral sensitivity test feature shall be provided. Detector range shall be up to 300 feet. Detector shall alarm when smoke level between the detector and reflector reaches the predetermined threshold. Threshold shall be field settable.

2. Reflector shall be mounted be adhesive on glass elevator wall. Align detector and reflector in the field for maximum signal strength.

I. Linear Heat Detector

1. Detector Cable: Comply with UL 521. The cable shall be suitable for ambient temperatures up to 150 deg F. The alarm temperature shall be 190 deg F. The cable shall be rated for outdoor use and shall be suitable for installation in a vehicular tunnel environment. Cable includes two steel actuator wires twisted together with spring pressure, wrapped with protective tape, and finished with
polyethylene outer sheath. Each actuator wire is insulated with heat-sensitive material that reacts with heat to allow the cable twist pressure to short circuit wires at the location of elevated temperature.

2. Control Panel: Suitable for multiple detectors. Provides same system power supply, supervision, and alarm features as specified for the FACP.

3. Signals to the FACP: Any type of local system trouble is reported to the FACP as a composite "trouble" signal. Alarms on each detection zone are individually reported to the FACP as separately identified zones.

4. Integral Addressable Module: Arranged to communicate detector status (normal, alarm, or trouble) to the FACP for each detector zone.

5. Mounting: Linear heat detector shall be mounted to the tunnel ceiling as shown in the plans using a cable messenger. Stand-off brackets with a rubber grommet shall be installed every 50 feet. Turnbuckles shall be installed on the cable messenger at minimum intervals of 250’.

J. Voice Evacuation System (VES)

1. General Requirements for VES panel:
   a. Field-programmable, microprocessor-based, modular, power-limited design with electronic modules, complying with UL 864 and listed and labeled by an NRTL. Panel shall be listed for fire alarm service.
      1) System software and programs shall be held in flash electrically erasable programmable read-only memory (EEPROM), retaining the information through failure of primary and secondary power supplies.
   b. Include a real-time clock for time annotation of events on the event recorder and printer.
   c. Digital Message Repeater Capable of storing messages
   d. Digital Signal processor for digital audio, tone generation and controls.
   e. Built in microphone for field messaging.
   f. Alphanumeric Display and System Controls Display alarm, supervisory, and component status messages and the programming and control menu.
   g. Style Y audio risers; 25 or 70.7 VRMS Audio signals
   h. Support distributed amplification for audio circuits.
   i. Integral power supply and back up batteries.

2. General Requirements for Notification Appliances: Connected to notification appliance signal circuits, zoned as indicated.
   a. Combination Devices: Factory-integrated audible and visible devices in a single-mounting assembly, equipped for mounting as indicated.
3. **Speakers**: Comply with UL 1480. Field selectable speaker voltage and power setting. Speaker shall have a frequency range of 400 to 4000 Hz.

4. **Visible Notification Appliances**: Strobe lights comply with UL 1971, with clear or nominal white polycarbonate lens mounted on an aluminum faceplate. The word "FIRE" is engraved on the lens.
   a. Rated Light Output: 15/30/75/110 cd, selectable in the field.
   b. Mounting: Wall mounted unless otherwise indicated.
   c. For units with guards to prevent physical damage, light output ratings shall be determined with guards in place.
   d. Flashing shall be in a temporal pattern, synchronized with other units.
   e. Mounting Faceplate: Factory finished, red

K. **Remote Indicators**
   1. Indicator (LED or lamp) for flush mounting in ceiling or wall. Normal condition shall be compatible with area smoke detector indicators (i.e. illumination upon alarm, extinguish upon return to normal).

L. **Magnetic Door Holders**
   1. Description: Units are equipped for wall or floor mounting as indicated and are complete with matching doorplate.
      a. Electromagnet: Requires no more than 3 W to develop 25-lbf holding force.
      b. Wall-Mounted Units: Flush mounted unless otherwise indicated.
      c. Rating: 120-V ac.

M. **Addressable Interface Device**
   1. Description: Microelectronic monitor module, NRTL listed for use in providing a system address for alarm-initiating devices for wired applications with normally open contacts.
      2. Integral Relay: Capable of providing a direct signal to elevator controller to initiate elevator recall, to circuit-breaker shunt trip for power shutdown or to solenoid valve for activation of exposure protection system.

N. **Wire and Cable**
   1. Wire shall be rated for the application and the environment it is installed.
   2. Wire shall be RHW, #18 AWG minimum, rated for fire alarm service.
   3. Cable for communication connection with the tunnel FACP shall be 6 fiber SMFO, suitable for installation in tunnel, damp environment, HDPE insulation, 0.7dB @1310 nm typical attenuation, compatible with Fire Alarm Control Panel.
PART 3 - EXECUTION

3.01 INSTALLATION

A. The installation of the system shall meet all requirements of NFPA 70 and NFPA 72.

B. Circuit breakers in the panels feeding the control panel shall be fitted with suitable guard, such that the breaker cannot be turned off, but fixed so the breaker can trip and requiring the removal of a screw to remove the guard. Separate breakers shall be provided for each control panel main power and trouble circuits.

C. Conductors shall be copper and shall be of the type and size specified herein or as required to meet the voltage drop requirements of the circuit.

D. Ground fire-alarm control panel and associated circuits; comply with IEEE 1100 and with Section 26 05 26, Grounding and Bonding for Electrical Systems. Install a ground wire from main service ground to fire-alarm control panel.

E. Junction boxes containing fire alarm circuits shall be painted red.

F. Remote Indicators: Provide in an adjacent area where readily visible for all concealed detectors.

G. Smoke detector spacing shall be in accordance with the listed spacing, the manufacturers recommendations and the requirements of NFPA 72. Detectors shall not be located within 5 feet of a supply air register nor within 12 inches of a lighting fixture.

H. Visual Indicators

1. Locate to meet the requirements of ADA and the City of Seattle.

I. Devices

1. Make addressable connections with a supervised interface device to the following devices and systems. Install the interface device less than 3 feet from the device controlled. Make an addressable confirmation connection when such feedback is available at the device or system being controlled.
   
   a. Smoke dampers in air ducts of designated air-conditioning duct systems.
   b. Connection to elevator recall system and components.
   c. Connection to Fire suppression systems
   d. Connections at valve supervisory switches.
   e. Flow or pressure switch of each sprinkler system.
   f. Supervisory connections at elevator shunt trip breaker.

2. Relays and other devices to be mounted in auxiliary panels are to be securely fastened to avoid false indications and failures due to shock or vibration.
J. Wiring

1. Within Sub-panels: Shall be arranged and routed to allow accessibility to equipment for adjustment and maintenance.

2. Each conductor shall be identified as shown on the installer drawings with wire markers at every splice and terminal point. Mark both ends with alphanumeric wire markers.

3. Detector wiring shall be Class A, Style D in accordance with NFPA 72. Notification circuits shall be Style Z. Control circuits shall be Class B with an end of line resistor on the last device on the circuit.

4. Wiring for fire alarm system shall be kept physically and electrically separate from all other power and signal system wiring.

5. Provide conductors and power supplies of sufficient size to minimize voltage drop consistent with the proper operation of all devices.

K. Auxiliary Controls

1. Destructible link smoke dampers shall not be connected to the fire alarm system. Fan Shutdown Control Circuits, Smoke Removal Control Circuits supervised (subject to NFPA 72 requirements) and may be incorporated into the fire alarm raceway system, except that limited energy circuits shall be routed separately from line voltage circuits as required by the National Electrical Code (NFPA 70).

3.02 CONSTRUCTION

A. System Operation

1. Activation of any alarm initiating device (smoke detector, water-flow switch, heat detector, etc.) shall cause the following actions and indications:

   a. Initiate an alarm signal at main control panel (FACP).
   b. Indicate the fire device and/or fire zone on the FACP.
   c. Selectively operate evacuation alarm signaling on the floor of fire detection or as otherwise programmed.
   d. Close all fire doors, smoke doors, and ventilator hatches, etc. on or associated with the respective floor of alarm.
   e. Signal elevator controllers for primary and alternate floor recall if applicable.
   f. Report system status to the Central Control System through the BMS.

2. Activation of any supervisory condition causing device (tamper switch, valve supervision device,) shall initiate a supervisory alarm signal at main control panel, and the BMS.

3. Any system trouble caused by wiring failure including open circuits, grounded circuits and shortsed circuits on circuitry required to be supervised in this manner; communications loss, device removal, battery low voltage, power loss, charger failure or failure in any device shall cause the following actions and indications:
a. Initiate a fire alarm system trouble signal at the FACP.

b. Transmit the trouble condition to the BMS.

4. All signal circuits including evacuation circuits, water flow indication circuits, trouble circuits and supervisory indicating circuits shall be silencable by means of a switch on the control panel front. Subsequent alarm receptions shall cause the alarm signals to resound indicating the reception of a new alarm condition. The signals shall also be caused to resound by the re-operation of the signal silence switch allowing evacuation signaling from the silence switch without keyboard commands when an alarm condition exists.

3.03 FIELD QUALITY CONTROL

A. Test Equipment

1. Provide all test equipment, instruments, tools and labor required to conduct the system tests.

2. The installer shall use test instruments that bear valid calibration stamp showing date of calibration and the expiration date of the stamp. Calibration and accuracy of test instruments shall be certified by an independent testing laboratory having standards traceable to the National Institute of Standards and Technology.

   a. All alarm and control functions.

   b. All trouble and supervisory functions.

   c. Transfer to battery power.

B. Acceptance Testing

1. Installer shall be responsible for acceptance testing in accordance with the ATP, demonstrating the functionality of the system and verifying the correct operation of all system components, circuits, and programming.

2. A program matrix shall be prepared, by the installer, referencing each alarm input to every output function affected as a result of an alarm condition on that input. In the case of outputs programmed using more complex logic functions involving "any", "or", "not", "count", "time", and "timer" statements; the complete output equation shall be referenced in the matrix.

3. A complete listing of all device labels for alphanumeric annunciator displays and logging printers shall be prepared prior to the ATP.

4. The installer's acceptance inspector shall use the system record drawings, in combination with the documents specified herein, during the testing procedure to verify operation as programmed. In conducting the acceptance test, the acceptance inspector shall request demonstration of any or all input and/or output functions.

5. System wiring shall be tested to demonstrate correct system response and correct subsequent system operation in the event of:

   a. Open analog loop.

   b. Shorted analog loop.
c. Grounded analog loop.
d. Open communication link.
e. Shorted communication link.
f. Grounded communication link.
g. Open zone wiring.
h. Grounded zone wiring.
i. Open signal circuit wiring.
j. Shorted signal circuit wiring.
k. Grounded signal circuit wiring.
l. Initiating device removal.
m. Battery disconnected.
n. Primary power disconnected.

6. System evacuation alarm signaling shall be demonstrated as follows:
   a. All signals actuate as programmed.
   b. Signal audibility.
   c. System indications shall be demonstrated as follows:
      d. Correct message display for each alarm input.
      e. Correct annunciator light for each alarm input.

7. System charging current shall be normal trickle charge for a fully charged battery bank.

8. Demonstrate satisfactory operation to the Seattle Fire Department.

C. Certification
   1. Manufacturer’s representative shall submit a letter stating he has tested the system and found it acceptable in all respects.

D. Fire Department Acceptance
   1. In addition to the proof-testing specified, the installation shall be subject to test by the local Seattle Fire Department.

E. Training
   1. The installer shall furnish training to a minimum of four Sound Transit employees as follows:
      a. Training in the receipt, handling and acknowledgment of alarms.
b. Training in the system operation including manual control of output functions from the system control panel.

c. Training in the testing of the system including logging of detector sensitivity, walk test of devices and response to common troubles.

d. Training in the programming of the system, including writing program logic modules, entering into the software and uploading and downloading the program to the system.

e. The total training requirement shall be a minimum of 4 hours but shall be sufficient to cover all items specified.

F. Project Closeout

1. System documentation shall be furnished to the Resident Engineer and shall include but not be limited to the following:

a. System record drawings and wiring details including one set of reproducible masters and Contract Drawings.

b. System operation, installation, maintenance and programming manuals.

c. System menu-driven instructions for the alteration, addition or deletion of zones, modification, addition or deletion of zone messages and the modification, deletion or addition of logic modules as required for system operation.

d. Documentation of system voltage, current and resistance readings taken during the installation, testing and ATP phases of the system installation.

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**SECTION 31 09 00**

**GEOTECHNICAL INSTRUMENTATION AND MONITORING OF EARTHWORK**

**PART 1 - GENERAL**

1.01 **SUMMARY**

A. The majority of the instrumentation for the U250 Contract will be installed as part of the preceding U220 UW excavation support and tunneling contract. For a summary of the instrumentation previously installed, refer to the U220 Instrumentation Installation, Monitoring and Transition Plan.

B. This Section includes specifications for furnishing, installing, maintaining, monitoring and decommissioning instrumentation which monitors earth and structure movements, groundwater drawdowns, and structural loads during Work.

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 12 19, Contract Interface.
2. Section 01 45 00, Quality Control.
3. Section 01 57 15, Temporary Construction Noise and Vibration Control.
4. Section 01 71 30, Protection and Maintenance of Property and Work.
5. Section 03 05 15, Portland Cement Concrete.

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


4. American Association of State Highway and Transportation Officials (AASHTO):

5. American Society for Testing of Materials International (ASTM)
1.03 DEFINITIONS

A. Instrumentation Well: A well in which pneumatic or electric geotechnical or hydrological instrumentation is permanently or periodically installed to measure or monitor subsurface strength and movement. Instrumentation 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 measures to be implemented.

E. Well: Water wells, resources protection wells, instrumentation wells, dewatering wells, and geotechnical soil borings.

1.04 SUBMITTALS

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

B. Instrumentation Monitoring Plan

C. Corrective Action Plan

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 and surveyor.

G. Copies of Start Cards and approved variances for all Instrument Wells.

H. Logs of borings of Instrumentation Wells, including sample data (depth, SPT N-Values) and Soil Descriptions of each sample.

I. 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.

J. Well Decommissioning Work Plan.

K. 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.

L. Final Instrumentation Summary Report.

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 5 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 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. For any additional work required in the Shoreline Management Zone, notify Sound Transit prior to commencing work. Modifications to the shoreline permit are required prior to performing any work in this Zone. No work will be permitted prior to obtaining approval from Sound Transit.

4. Coordinate activities affecting utilities with the appropriate utility company.

5. Pre-construction utility surveys: In accordance with Section 01 71 30, Protection and Maintenance of Property and Work.

6. Pre-construction building survey: 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 University of Washington Station as part of the previous U220 contract. Maintain, monitor, repair, and if damaged replace this instrumentation.

2. Coordinate with the U220 contractor and the Resident Engineer to use the existing Instrumentation Data Management System (IDMS) for monitoring and reporting readings.

3. Coordinate with the U220 contractor and the Resident Engineer to take over responsibilities for maintaining and monitoring instrumentation and the IDMS around the University of Washington Station.

4. Reference Section 01 12 19, Contract Interface, and the Contract Drawings for additional information and requirements.

1.07 INSTRUMENTATION MONITORING PLAN

A. Instrumentation to be installed by U250 Contractor.

1. Schedule and outline of procedures and timing for installation of instrumentation wells for electromagnetic instrumentation.
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.

B. Instrument Monitoring

1. Baseline or Initial Readings of Existing Instruments.

2. Routine Monitoring

3. Action Level Monitoring

4. System Maintenance

5. Instrument replacement procedures
   a. If an instrument is repaired, replaced or moved subsequent to installation, record new: instrumentation type, as built location, and calibration sheets. Report to the Resident Engineer the reason the original instrument was altered and the date the new instrument was operational.

C. Reporting of Monitoring Data

1. Description of any changes or alterations to the existing Instrumentation Data Management System (IDMS) necessary for new instrumentation including:
   a. How data is posted to IDMS.
   b. Reports generated in IDMS.
   c. Alarms and notification through IDMS.
   d. How access is controlled to IDMS and by whom.

1.08 CORRECTIVE ACTION PLAN

A. Details of actions to be taken in the case that settlement, lateral movement, or groundwater drawdown exceed the Trigger or Maximum Levels indicated on the Contract Drawings.

B. Provide specific actions for the 54-inch steel riveted/lockbar water main, approximate Stations 1188+00 to 1210+00.

C. Include operational changes to reduce the rate of soil movement and groundwater drawdown.

1.09 WELL DECOMMISSIONING WORK PLAN

A. Submit at least 60 days prior to beginning the decommissioning work. Allow 14 calendar days for the Resident Engineer to review the Plan.
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.

1.10 FINAL INSTRUMENTATION SUMMARY REPORT

A. After substantial completion but prior to project close out provide a summary of all instrumentation activities. Include the following:

1. Final measurements of all instruments.
2. List instruments for which monitoring levels exceeded the trigger limit.
3. List instruments for which monitoring levels exceeded the maximum limit.
   a. For these instruments describe actions taken to prevent further movement and any remedial work performed.

PART 2 - PRODUCTS

2.01 GENERAL

A. The only new instrumentation installed by the U250 contractor are the boreholes for the electromagnetic interference monitoring locations.

B. Existing instrumentation installed during previous contracts may require repairs or replacement during the U250 contract. This section includes requirements for materials and installation procedures associated with repairing or replacing these instruments.

C. Verify all instruments and equipment are the manufacturer’s standard products without modifications except those that may be noted below.

D. 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”.


E. 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.

F. 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.

G. Unless otherwise indicated, 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 instrument and datalogger unless absolutely necessary.

2.02 MATERIALS

A. Grout mix for all instrumentation installations: Mixture of 94 pounds of portland cement, 25 pounds of bentonite, and 30 gallons of water. (Grout Ration 1:0.3:2.5)

B. Cement: Portland Cement, per Section 03 05 15, Portland Cement Concrete.

C. Concrete: Class 3000 A mix per 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 ½ inch, Baroid Industrial Drilling Products Company or approved equal.

F. 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 Points: As shown on the Contract Drawings, or use adhesive-
   backed targets, Leica Models #635-317 (20 mm square), #635-318 (40 mm square), or
   #635-319 (60 mm square).

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 (20 mm 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 3 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 University of Washington Station.

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. Use the Instrument Data Management System (IDMS) established by the U220 Contractor.

B. The IDMS shall be capable of:

1. Storing and disseminating all monitoring data from vibrating wire instruments and other sensors associated with instruments described in this Section.

2. Automated processing of the instrumentation data to convert readings into meaningful engineering units.

3. Checks for action levels for each instrument and alerts the Resident Engineer and Contractor in the event an action level is reached.

4. Displays graphs of instrumentation data.

5. Generates reports of instrumentation data.

6. Access to the information is controlled.

7. 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. Except for strain gages mounted on bracing members, install all instruments and make operational, with stable baseline readings, a minimum of four weeks prior to the start of shoring, excavating, or other work requiring monitoring.

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. 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.

G. Provide surveyed location of each instrument within 5 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. For existing instruments, installation procedures are given below if replacement is required due to damage during construction.

2. 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.

3. Adhere to manufacturer’s requirements for alignment of instruments.

4. Follow manufacturer’s precautions on handling. Many of these instruments are susceptible to damage if not handled properly.

5. 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).

B. Inclinometers

1. Install inclinometer casings to the depths of the original instrument.

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 5-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 of the original instrumentation.

3. Install electrical reference head, and hook up to datalogger.

4. Provide protective enclosure as specified herein.

G. Soldier Pile Shoring Monitoring: Install a structure settlement point on the top of every other soldier pile, in addition to other instrumentation indicated on the Contract Drawings.

H. Wall Survey Points: As indicated on the Contract Drawings.

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 monitoring points, wall survey points: Total movements.
   
b. Extensometers 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) Perform leak tests on the 54-inch steel water main between approximately Stations 1188+00 and 1210+00. Coordinate testing and leak repairs with Seattle Public Utilities (SPU).

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. For 54-inch steel water main between approximately Stations 1188+00 and 1210+00: 0.75 inch.

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 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 for bracing members: 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 C: Decommission after construction, but prior to final Substantial Completion.

2. Schedule D: Decommission well prior to placement of the bottom slab.
3. Schedule E: Do not decommission well. Well will be monitored and decommissioned as part of a subsequent contract.

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
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for clearing, grubbing, and disposing of vegetation, including bushes, brush, trees, stumps, logs, 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 01 57 13, Temporary Erosion and Sediment Control
4. Section 02 41 00, Demolition
5. Section 31 20 00, Earth Moving

PART 2 - PRODUCT

2.01 MATERIALS AND EQUIPMENT

A. Furnish materials, tools, equipment, facilities, and services as required for performing site clearing, grubbing, and other site preparation work.

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 work. Comply with the requirements of Section 01 35 93, Archaeological Finds.

B. Protect survey markers and monuments, existing improvements, and adjacent properties from removal and damage.

C. Care of Existing Trees and Plants: Protect trees and plants indicated and as specified in Section 01 56 39, Temporary Tree and Plant Protection.

D. 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.
E. Coordinate the work of this Section with the work of Section 02 41 00, Demolition.

F. Perform work in accordance with the requirements of Section 01 57 13, Temporary Erosion and Sediment Control.

3.02 CLEARING AND GRUBBING

A. Clear and grub 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 trees, plants, grass, roots and debris from the existing ground.

B. Use extra care when clearing and grubbing within the critical root zone (CRZ) of trees to remain to avoid unwanted root damage. Perform clearing and grubbing in the CRZ under the supervision of the Resident Engineer and the Project Arborist. When clearing and grubbing in areas that are in the CRZ and are to be paved, coordinate with the Resident Engineer and Project Arborist for the establishment of the subgrade elevation and for root trimming and/or protection measures.

C. Coordinate with salvaging of topsoil as specified in Section 31 20 00, Earth Moving.

D. Remove stumps and roots completely in excavation areas, utility trenches and under embankments where the original ground level is within 3.5 feet of subgrade or slope of embankments. In embankment areas, where the original ground level is more than 3.5 feet below the subgrade or slope of embankment, cut off trees, stumps, and brush to within 6 inches of the existing ground.

E. Do not start earthwork operations in areas where clearing and grubbing are not complete. Stumps and large roots may be removed concurrently with excavation.

F. Where the work includes requirements for wood chip mulch, acceptable material from clearing and grubbing activities may be used to produce such mulch.

G. Tree Trimming: Remove tree branches in designated areas of the site according to Section 01 56 39, Temporary Tree and Plant Protection.

H. Clear and restore areas used for the Contractor's convenience. Restore such areas to their original condition, and provide mulching, seeding, and planting as required.

I. Backfill: Backfill excavations resulting from work under this Section in accordance with applicable requirements of Section 31 20 00, Earth Moving.

J. Disposal of Cleared Vegetation, Grubbed Material and Waste:

1. Dispose of removed materials, waste, trash, and debris in a safe 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. Locating disposal sites and length of haul is the Contractor's responsibility.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 31 20 00

EARTH MOVING

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 02 41 00, Demolition
2. Section 03 34 00, Cellular Concrete Fill
3. Section 31 11 00, Clearing and Grubbing
4. Section 31 23 19, Dewatering
5. Section 31 23 33, Trenching and Backfilling
6. Section 31 50 00, Excavation Support and Protection
7. Section 32 11 23, Aggregate Base Courses
8. Section 33 01 00, Operation and Maintenance of Utilities

1.02 REFERENCES

A. This Section incorporates by reference the latest revision 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, conditioned 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 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: Mineral Aggregate Type 17 accordance with COS Standard Specifications Section 9-03.14.

E. Structural backfill Controlled Density Fill (CDF) in accordance with COS Standard Specification 2-09.3(1)E.

F. Cellular Concrete Backfill where indicated: Section 03 34 00, Cellular Concrete Fill.

G. Materials for Trenching, Bedding, and Backfilling of utilities in accordance with Section 31 23 33, Trenching and Backfilling.

H. 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) 514-3499 or approved equal.

I. Aggregates for pavement bases: Section 32 11 23, Aggregate Base Courses.

J. 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

2.02 SOURCE QUALITY CONTROL

A. Ensure that the material used complies with the specifications by using the following methods of testing: For materials specified to meet the COS Standard Specifications, comply with COS Standard Specification Section 9-03.15 for test methods. For materials specified to meet the WSDOT Standard Specifications, comply with WSDOT Standard Specification Section 9-03.20 for test methods. In addition to those specified above, use the following test methods:
   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 or hydro vacuum excavation.
   2. Remove already 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: Prevent erosion of the site at all times. 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. Comply with requirements of Section 01 56 39, Temporary Tree and Plant Protection.

E. Comply with Section 01 35 93, Archaeological Findings.

3.03 CONSTRUCTION

A. Earthwork General Requirements
   1. Dust Control: Refer to Section 01 57 19, Temporary Environmental Controls.
   2. 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.
   3. 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.
4. Trenching and backfilling for utilities: Refer to Section 31 23 33, Trenching and Backfilling.

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 disposed of in accordance with Section 01 74 00, Cleaning and Waste Management.
   b. Comply with the City of Seattle Standard Specification Section 2-03.3(7) and its referenced sections.
   c. Comply with Section 02 41 00, Demolition.
   d. 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.

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 Systems, 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 bottom 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.
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. Compacted backfill is required around all substructures. Fill holes, pits, and other voids with structural fill and provide compaction in accordance with Article 3.03.I, herein.

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 to Class I compaction, and not more than four inches of loose depth for material to be compacted to Class II compaction.

5. Place and compact 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.

6. Do not backfill around portions of cast-in place concrete vaults, manholes or catchbasins requiring backfill on only one side or on less than all sides, until the concrete has reached the specified 28-day strength.

G. Subgrade for Surfacing

1. Comply with COS 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 rough grade to the depth required below finished grade to allow placement of specified thicknesses of topsoil and mulch 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.

b. Backfill around Structures: Class II for top 12 inches, Class I below top 12 inches.

c. 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.

d. 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.

4. Original Ground or Cut Subgrade:
   a. Scarify the surface and provide Class II compaction for full width of pavement plus 3 feet on each side thereof.
   b. 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. Perform an initial test whenever material changes or source changes then follow minimum frequency below.

   2. Expansive Horizontal Areas: One test per 100 cubic yards of each material type, or fraction thereof, of fill or backfill placed.

   3. 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
CONTRACT SPECIFICATIONS

SECTION 31 23 19
DEWATERING

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for designing, furnishing, installing, maintaining, operating, and removing temporary dewatering systems and controls as required to control water levels and hydrostatic pressures during demolition and excavation; treatment and disposing of pumped water; constructing, maintaining, observing and, except where indicated or required to remain in place, removing equipment and instrumentation when no longer needed.

B. Dewatering includes intercepting seepage within the bottoms of excavations; increasing the stability of excavations; preventing loss of material from bottoms of excavations; 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 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork.
2. Section 31 50 00, Excavation Support and Protection.
3. Section 31 66 17, Slurry Diaphragm Wall Cleaning and Repairing.

1.02 SYSTEM DESCRIPTION

A. Design Guidelines

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 below bottom level of excavation throughout construction.

   b. Develop a substantially dry and stable subgrade for prosecution of construction operations.

   c. Prevent damage to adjacent buildings, structures, utilities, and other work that may result from settlement or other groundwater-related effects. Ensure dewatering design has been reviewed and approved by the impacted utility authorities before 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. Methods for creating groundwater cutoff barrier system may include use of secant piles, slurry walls, and combinations thereof, per Section 31 50 00, Excavation Support and Protection, and Section 31 66 17, Slurry Diaphragm Wall Cleaning and Repairing.

4. Locate dewatering facilities where they will not interfere with utilities and construction work to be performed by others.

5. Hydrostatic uplift force acting on base of structure. Do not exceed 95 percent of dead weight of construction in place.

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.
   4. Types and sizes of filters.
   5. Design calculations demonstrating adequacy of the proposed systems and equipment.
   6. Methods of disposal of pumped water.

C. Submit qualifications of dewatering system designer and operator.

D. Submit copies of the special permits required for performing the work of this Section.

E. Submit records as specified herein.

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, 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. Conduct groundwater discharge, conveyance and transmission to off-site locations in a manner that meets with the approval of the governmental authorities having jurisdiction, and 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 prosecution of the work, and to provide a stable, dry subgrade for the prosecution of construction operations.

4. Maintain existing water levels outside of foundation excavations.

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.

B. Groundwater Cutoff Barrier System

1. A minimum of two piezometers shall be used to monitor groundwater pressure outside of groundwater cutoff barrier.

2. Achievement of satisfactory groundwater cutoff barrier shall be based, as a minimum, on submitted readings from piezometers located within and outside of limits of foundation excavation.

3. Groundwater level or piezometer readings will be taken as specified in Section 31 09 00, Geotechnical Instrumentation and Monitoring of Earthwork, while foundation construction is underway until foundation concrete is placed.
4. Properly plug holes drilled in concrete slab for probing or monitoring groundwater.

3.02 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 appropriate devices, such as flow meters, for observing 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.

END OF SECTION
SECTION 31 23 33
TRENCHING AND BACKFILLING

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 31 20 00, Earth Moving
2. Section 31 23 19, Dewatering
3. Section 31 50 00, Excavation Support Systems

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 (SDOT):
   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. Provide list of source location 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 pipe bedding: Class B bedding in accordance with COS Standard Plan 285. Mineral Aggregate Type 9 in accordance with COS Specification Section 9-03.

5. 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. Staking and Grades:

1. Refer to Section 01 71 23, Field Engineering, for requirements.

B. Existing Utilities:

1. Refer to Section 31 20 00, Earth Moving, Article 3.01B.

C. 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.

D. 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.

E. Trenching and Excavating:

1. Perform work per 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 or as referenced in a Standard Plan.

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 ft.

6. The maximum trench width in the Right of Way shall not exceed the neat line trench width indicated.

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 or referenced in a COS standard plan, 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. If the trench bottom is disturbed, compact to 90 percent for a depth of 12 inches.

9. Grade surrounding areas or utilize alternative controls to prevent surface water from flowing into 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. Remove ledge-rock, boulders, stones, and any object larger than 3 inches in any dimension lying within 6 inches from the pipe.
13. Notify the Resident Engineer if over-excavation is required and/or material in trench bottom is determined unsuitable.

14. Remove unexpected objects such as stumps, logs, railroad ties, buried pavement, etc encountered in the trench excavation. Notify the Resident Engineer if removal of unexpected objects requires an increase in trench size or if the object(s) cannot be removed by the equipment or excavation method at hand.

15. 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.

16. Ensure excavations for structures conform to the applicable requirements of Section 31 20 00, Earth Moving.

F. 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 except when used within embedment concrete.
   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.


G. 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 evenly from both sides 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.
H. 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.

I. Restoration:

1. Comply with surface restoration requirements as indicated in the Contract Drawings, 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
CONTRACT SPECIFICATIONS

SECTION 31 50 00
EXCAVATION SUPPORT AND PROTECTION

PART 1 - GENERAL

1.01 SUMMARY:
A. This Section includes specifications for designing, furnishing, installing, monitoring, leaving in place, and removing excavation support systems. Locations and extent of these systems are shown on the Contract Drawings.
B. This Section applies to both Sound Transit-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 revision 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: A horizontal shoring element supporting soldier piles or wales and supported by embedment into and friction against grade. Anchor tiebacks carry axial tension and are typically steel rod or steel wire strand.

B. Design Load: The calculated load carried by a shoring element.

C. Drainage Mat: A manufactured material available in sheets or rolls used behind lagging to prevent buildup of hydrostatic pressure.

D. Existing Construction: Adjacent structures, facilities, equipment, conveyances, and utilities present at the beginning of excavation.

E. Lagging: A vertical shoring element restraining the horizontal movement of a cut soil face and supported by soldier piles or wales. Lagging is typically timber, precast concrete, or shotcrete.

F. Parcel: An area of ground as indicated, including all existing construction upon or connected to it.

G. Raker: A sloping strut, typically supported on grade.

H. Restore: To return to pre-excavation condition by repair or replacement of portions damaged, altered, or removed by excavation activities.

I. Sheet: A vertical shoring 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.

J. Sheet Pile: A vertical shoring 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.

K. Shore: A horizontal, inclined, or vertical shoring element positioned against or beneath a structure, part of a structure, or utility to restrain movement.

L. 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.

M. Soldier Pile: A vertical shoring 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

N. Strut: A horizontal shoring 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.

O. Tangent Pile: A vertical shoring 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.
P. Tremie: A pipe used to place concrete under water or slurry, displacing the water or slurry during placement.

Q. Tremie Concrete: Concrete placed under water or slurry using a tremie.

R. Underpinning: A vertical shoring element supporting the vertical load of a structure, part of a structure, or utility, supported by embedment into grade.

S. Wale: A horizontal shoring element supporting lagging, sheets, sheet piling, or soldier piles, and supported by anchor tiebacks or struts.

T. Working Drawings: For contractor-designed systems, drawings describing the excavation support system.

1.04 SUBMITTALS

A. General: 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: Submit certification that all welders are qualified according to the Washington Association of Building Officials (WABO).

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.

1.06 EXCAVATION SUPPORT DESIGN REQUIREMENTS

A. Excavation support systems designed by the Contractor shall meet the following criteria:


3. Support earth pressures as noted on the 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. Maximum lateral deflection of any system within 40 feet of City right-of-way is limited to 1 inch.

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 shoring wall movement. Mitigating measures shall be approved by the Resident Engineer.

B. If the 1 inch deflection criteria is exceeded:

1. Notify the Resident Engineer immediately.

2. Increase frequency of readings and 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, and Section 03 05 15, Portland Cement Concrete, for requirements.

C. Metals: For all metal materials other than steel sheet piling refer to Section 05 12 00 Structural Steel Framing. For steel sheet piling use ASTM A328, continuous interlocking type.

D. Tiebacks: Refer to Section 31 51 00, Anchor Tiebacks.

E. 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 permanently in place with preservative material in accordance with AWPA U1, Use Category 4A, Commodity Specification A.

F. 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 shoring at the locations depicted on the Contract Drawings. 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 potholed, 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. Prior to start of drilling, review provided site subsurface data to determine whether casing will be required. The cost of any casing shall be incidental to the shoring 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.

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.

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 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 LAGGING

A. Install lagging as excavation progresses.

B. Do not allow more than 4 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.

3.05 SUPPORT SYSTEMS WITH INTERNAL BRACING

A. General: Provide wales, struts, and rakers as necessary to support excavation faces retained by soldier piles and lagging, or by tangent-piles.

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.

3.06 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.

3.07 EXCAVATION BELOW TIEBACKS AND BRACING

A. Tieback, wale, strut and raker installation testing and stressing shall be completed prior to excavating more than 2 feet below centerline of tieback or bracing level.

3.08 TOLERANCES

A. Soldier Piles and Sheet Piles:

1. Install tops of soldier piles and sheet piles within 3 inches, plus or minus, horizontally of the locations shown on the approved Working Drawings or Contract Drawings.

2. Install tops of soldier piles and sheet piles within 6 inches, plus or minus, vertically of the locations shown on the approved Working Drawings or Contract Drawings.

3. Install steel soldier piles and sheet piles within 1.5 percent of plumb.

3.09 REMOVAL OF EXCAVATION SUPPORT SYSTEMS

A. If removal is required wholly or in part, perform such removal in a manner that will not disturb or damage adjacent structures, construction, or utilities. Fill voids immediately with lean concrete or with approved backfill compacted to the relative compaction for the location as specified in Section 31 20 00, Earth Moving.
B. Leave excavation support systems in place until the concrete and structures to receive
the transferred loading from the removed support system have reached the specified
28-day compressive strength. Demonstrate by methods acceptable to Resident Engineer
that the concrete has reached the specified strength before load transfer from the support
system to the concrete structure may be performed. Do not remove bracing supporting
pile caps or base slabs for a minimum 7 days after last concrete has been placed.

C. Remove from the Site all elements of excavation support systems 4 feet below the level
of surfaces to be constructed or restored.

D. Repair damage to new or existing structures resulting from removal of excavation support
systems.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 31 51 00
ANCHOR TIEBACKS

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for designing, 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 Section.

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.

1.02 REFERENCES

A. This Section incorporates by reference the latest revision 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, and couplers if used.

B. Soldier Piles: Steel shapes installed vertically to take the thrust of horizontal lagging. Also called soldier beams.

C. Tremie Concrete: Concrete placed by means of tremie equipment, for depositing concrete under water and thereby displacing water in an excavation.
D. Waler: Horizontal beam used to brace or support vertical sheeting or piling.

E. Alignment Load: A nominal minimum load applied to a tieback anchor during testing to keep the testing equipment correctly positioned.

F. Bondbreaker: A sleeve placed over the anchor tendon in the free-stressing (unbonded) length to ensure unobstructed elongation of the tendon during stressing.

G. Encapsulation: A corrugated or deformed tube protecting the prestressing steel against corrosion in the tendon bond length.

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 tieback anchor 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. 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 a professional civil or structural engineer currently registered in the State of Washington.

C. Working drawings indicating tieback system and installation procedures including:

1. Anchor tieback schedule showing each tieback number, design load, tendon type and size of anchor, minimum total anchor length, minimum bond length, minimum tendon bond length, and minimum unbonded length.

2. Drawings for tendons including details for spacers and locations, centralizers and locations, and 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 calendar 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 tieback anchor, anchor capacity, tendon type, total anchor length, tendon bond length, and locations of all instruments.

H. Provide test data and results for all testing as 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, 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 Section 31 50 00, Excavation Support and Protection.

C. Steel Wales: In accordance Section 31 50 00, Excavation Support and Protection.

D. Ensure tieback system materials meet the following requirements:
1. Anchorage Devices:
   a. 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 devise d conforms to the
      static strength requirements of the PTI Post Tensioning Manual.
   b. Bearing Plates: Conform to the requirements of AASHTO M183 or M222
      or approved equal.

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:
   a. Resistant to chemical attack from aggressive environments, grout or
corrosion inhibiting compound;
   b. Resistant to aging by ultra-violet light;
   c. Fabricated from material non-detrimental to tendon;
   d. Capable of withstanding abrasion, impact, and bending during handling
      and installation;
   e. Enables tendon to elongate during testing and stressing;
   f. 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 2 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:
a. Steel bars conforming to AASHTO M275  
b. Seven-wire, low-relaxation strands conforming to AASHTO M203  
c. 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 a 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.  

B. No part of the tieback wall will be allowed to intrude within the limits of permanent structures.  

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. Install a minimum bond length of 15 feet for strand and bar tendons.

C. Extend the free stressing length (unbonded length) for tiebacks beyond the no load zone as shown on the Contract Drawings.

D. Ensure all anchors are 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.

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 redrill 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.** Do not load tendon for a minimum of three days after grouting. 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. Ensure wedge holes and wedges are free of rust, grout, and dirt.

### 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 successful performance tests on at least two tieback anchors, as selected by the Resident Engineer. The contractor should anticipate that up to 8 performance tests may be required. 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. Adhere to 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>
</thead>
<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>
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<tr>
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<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></th>
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</thead>
<tbody>
<tr>
<td>Alignment Load (AL)</td>
<td>0.25P</td>
</tr>
<tr>
<td></td>
<td>0.50P</td>
</tr>
<tr>
<td></td>
<td>0.75P</td>
</tr>
<tr>
<td></td>
<td>1.00P</td>
</tr>
<tr>
<td></td>
<td>1.20P</td>
</tr>
<tr>
<td></td>
<td>1.33P = Maximum proof test load; Evaluate creep</td>
</tr>
<tr>
<td></td>
<td>Reduce to lock-off load (0.80P)</td>
</tr>
</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 REMOVAL

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 DESCRIPTION

A. This Section includes specifications for furnishing all materials, labor, tools, equipment, services, and incidentals necessary to construct drilled shaft foundations in accordance with the Contract Drawings.

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 30 00, Cast-In-Place Concrete

1.02 REFERENCES:

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

1. American Petroleum Institute (API)
   a. API 13B-1 Recommended Practice for Field Testing Water Based Drilling Fluids

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

1.03 DEFINITIONS

A. Disturbed Soil: Soil whose geotechnical properties have been changed from those of the original in-situ soil, and whose altered condition adversely affects the structural integrity of the shaft foundation.

B. Obstruction: A specific object which significantly reduces the rate of drilling relative to the rate of advance of the drilling for the rest in the geological unit containing the obstruction. Logs and timber piling will not be considered obstructions.

C. Open Shaft Excavation: A shaft excavation that has not been filled with concrete or temporarily backfilled.

D. Pause: A momentary interruption of the drilling operation to splice casing, change tools, maintain slurry, or remove obstructions.

E. Permanent Casing: Casing designed as part of the shaft structure and to remain in place after construction is complete.
F. **Stop:** A momentary interruption of the drilling operation not conforming to the definition of a pause.

G. **Temporary Casing:** Casing installed only to facilitate shaft construction, and to be removed completely after construction is complete, unless otherwise shown in the Contract Drawings.

### 1.04 SUBMITTALS

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

B. **Qualifications:** Submit qualifications for the following demonstrating conformance:
   1. Drilling Contractor
   2. On-site supervisors
   3. Drill rig operators
   4. Personnel performing non-destructive testing
   5. Welders

C. **Concrete Mix Designs:** Section 03 05 15 Portland Cement Concrete

D. **Concrete Reinforcing:** Section 03 20 00, Concrete Reinforcing. Include bracing and any extra reinforcing steel required for fabrication, transportation, and installation; and details of the proposed reinforcing cage spacers.

E. **Shaft vibration monitoring plan,** including a description of the monitoring equipment and the installation and monitoring procedure.

F. **Construction Work Plan (CWP):** Submit a CWP providing at least the following information:
   1. An overall construction operation sequence and the sequence of drilled shaft construction. Reference the available subsurface data provided in the contract test hole boring logs and the geotechnical report.
   2. Description and capacities of proposed equipment, including but not limited to cranes, drills, auger, bailing buckets, final cleaning equipment, and drilling unit. Describe it's suitability to the anticipated site and subsurface conditions. Include a project history of the equipment demonstrating the successful use on shafts of equal or greater size in similar site and subsurface conditions.
   3. Description of shaft excavation methods, including proposed drilling methods, methods for cleanout of the shafts, and a disposal plan for excavated material and drilling slurry (if applicable). Include a review of method suitability to the anticipated site and subsurface conditions.
   4. Description of the methods to be used to ensure shaft stability (i.e., prevention of caving, bottom heave, etc. using temporary casing, slurry, or other means) during drilling and concrete placement. Include provisions for pauses and stops in drilling. Include a review of suitability to the anticipated site and subsurface conditions. If temporary casings are proposed or required, provide casing dimensions and procedures for installation and removal.
   5. Procedures for mixing, installing, maintaining, and disposing of the slurry (if applicable). Provide a detailed mix design and a discussion of its suitability to the anticipated subsurface conditions for the proposed slurry.
6. Plan for quality control of the selected slurry, including tests to be performed, test methods to be used, and minimum and/or maximum property requirements that must be met to ensure that the slurry functions as intended, considering the anticipated subsurface conditions and shaft construction methods, in accordance with the slurry manufacturer's recommendations. As a minimum, include the following tests:
   a. Density: Mud Weight (Density), API 13B-1
   b. Viscosity: Marsh Funnel and Cup, API 13B-1
   c. pH: Glass electrode, pH meter or pH paper
   d. Sand Content: Sand, API 13B-1

7. Description of method used to fill or eliminate all voids below the top of shaft between the plan shaft diameter and excavated shaft diameter.

8. Description of reinforcement placement. Include bracing, centering, and lifting methods, and the method to ensure the reinforcing cage position is maintained during construction.

9. Description of concrete placement. Include proposed pumping and/or tremie methods, and a sample uniform yield form to plot the volume of concrete place versus the depth of shaft.

10. Description of the methods used to construct the column, and the portion of the shaft above the upper construction joint and below existing ground.

11. Description of emergency horizontal construction joint during concrete placement.

12. Description of the device used to prevent unauthorized entry into a shaft excavation.

13. Description of the methods used to temporarily backfill a shaft excavation during a stoppage. Include backfill material used as well as the methods to place and remove the material.

14. Description of shaft vibration monitoring plan to the Resident Engineer for approval, including a description of the monitoring equipment, and the installation and monitoring procedure. The monitoring equipment shall be sensitive enough to detect a Peak Particle velocity of 1/4 inch per second.

G. Synthetic Slurry Technical Assistance

1. If synthetic slurry is used to construct the shafts, provide or arrange for technical assistance in the use of the synthetic slurry. Submit one of the following to the Resident Engineer for approval:
   a. The name and current phone number of the synthetic slurry manufacturer's technical representative assigned to the project.
   b. The name(s) of the Contractor's personnel assigned to the project and trained by the synthetic slurry manufacturer in the proper use of the synthetic slurry. The submittal shall include a signed training certification letter from the synthetic slurry manufacturer for each trained Contractor's employee listed, including the date of the training.
1.05 QUALITY ASSURANCE

A. Qualifications

1. Drilling Contractor: Successful completion of at least three separate bridge drilled shaft foundations projects within the past 5 years with drilled shafts equal to or larger than those shown in the Contract Drawings with similar site and subgrade conditions. Include contact information for the project owner’s representative.

2. On-Site Supervisors: A minimum 2 years experience in supervising construction of drilled shaft foundations with similar site and subgrade conditions.

3. Drill Rig Operators: A minimum 1-year experience in construction of drilled shaft foundations.

4. Non-Destructive Testing
   a. Organization: A minimum of three deep foundation projects in the last two years.
   b. Personnel: A minimum of one year experience in crosshole sonic log testing and interpretation.

5. The Resident Engineer may suspend the drilled shaft construction if the Contractor substitutes unqualified personnel.

B. Shaft Construction Tolerances:

1. Construct drilled shafts such that the center at the top of the shaft is within the following horizontal tolerances:
   a. Diameter less than or equal to two feet: 3 inches
   b. Diameter greater than two feet and less than five feet: 4 inches
   c. Diameter five feet and greater: 6 inches

2. Install shafts within 1.5 percent of plumb.

C. Reinforcing Placement Tolerances:

1. Top of reinforcing cage: + 6 inches, -3 inches
2. Spacing of bend and ends of bars: ±1 inch
3. Length of bar laps: -1 ½ inch

D. Shaft Vibration Monitoring: Provide and operate monitoring equipment able to detect a peak particle velocity of 1/4 inch per second.

E. Nondestructive Testing of Shafts

1. Provide access tubes.
2. Perform crosshole sonic log testing of specific shafts,

F. Preconstruction Conference
1. Hold a preconstruction conference at least 5 working days before beginning Work to discuss construction procedures, personnel, and equipment to be used, and other elements of the approved shaft installation plan. If synthetic slurry is used to construct the shafts, discuss the frequency of scheduled site visits by the manufacturer’s representative. The list of materials specified in the Record of Materials (ROM) form for this item of work will also be discussed. Those attending shall include:

   a. The superintendent on-site supervisors, and all foremen in charge of excavating the shaft, placing the casing and slurry as applicable, placing the steel reinforcing bars, and placing the concrete. If synthetic slurry is used to construct the shafts, the slurry manufacturer’s representative and the Contractor’s employee trained in the use of the synthetic slurry shall also attend.

   b. The Resident Engineer and key inspection and design personnel.

2. If the Contractor’s key personnel change, or if the Contractor proposes a significant revision of the approved shaft installation plan, an additional conference shall be held before any additional shaft construction operations are performed.

1.06 SEQUENCING AND SCHEDULING

   A. Schedule drilling or excavating, installation of reinforcing steel and concrete placement so that each excavated shaft is placed immediately after drilling or other excavating is complete and reinforcing steel is placed.

   B. Provide means to prevent heavy vibration or excessive wheel loads within the immediate vicinity of shaft excavation. Maintain stable excavation at all times.

PART 2 - PRODUCTS

2.01 TEMPORARY CASING (IF APPLICABLE)

   A. Smooth wall structure of steel base metal. All temporary casing shall be of ample strength to resist damage and deformation from transportation and handling, installation and extraction stresses, and all pressures and forces acting on the casing. The casing shall be capable of being removed without damaging the casing, deforming or damaging the completed shaft, and without disturbing the surrounding soil.

   B. The outside diameter of the casing shall not be less than the specified diameter of the shaft. The inside diameter of the casing for shafts greater than 5 foot diameter shall not be greater than the specified diameter of the shaft plus 6 inches, except as otherwise noted for temporary telescoping casing. The inside diameter of the casing for shafts 5 foot diameter or less shall not be greater than the specified diameter of the shaft plus 1 foot.

2.02 SLURRY (IF APPLICABLE)

   A. Mineral Slurry: Mineral slurry shall not be used.

   B. Synthetic Slurry: Acceptable products:

      1. Novagel, by Geo-Tech Services, LLC
      2. ShorePac GCV, by CETCO
      3. SlurryPro CDP, by KB International, LLC.
4. SuperMud, by PDS Company (liquid product only)

C. Water Slurry (with or without site soils)

1. Water with or without site soils may be used as slurry when casing is used for the entire length of the drilled hole. Use of water slurry without full-length casing may only be used with the approval of the Resident Engineer.

2. Provide water slurry with the following properties in conformance with API 13B-1. Slurry temperature shall be at least 40 degrees F when tested.

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<thead>
<tr>
<th>Property</th>
<th>Test Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (pcf)</td>
<td>Mud Weight (Density)</td>
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<tr>
<td>Viscosity (sec./quart)</td>
<td>Marsh Funnel and Cup</td>
<td>26 - 50</td>
</tr>
<tr>
<td>pH</td>
<td>Glass Electrode, pH Meter, or pH Paper</td>
<td>8 - 11</td>
</tr>
<tr>
<td>Sand Content (percent)</td>
<td>Sand, API 13B-1</td>
<td></td>
</tr>
<tr>
<td>before final cleaning</td>
<td></td>
<td>4.0 max.</td>
</tr>
<tr>
<td>immediately before placing concrete</td>
<td></td>
<td>4.0 max.</td>
</tr>
</tbody>
</table>

2.03 ACCESS TUBES FOR CROSSHOLE SONIC LOG TESTING

A. Steel pipe with minimum 0.145 inch wall thickness and minimum 1-1/2 inch inside diameter.

B. Round, regular inside diameter free of defects and obstructions, including all pipe joints, able to permit the free, unobstructed passage of 1.3-inch maximum diameter source and receiver probes.

C. Watertight, free from corrosion with clean internal and external faces to ensure good bond between concrete and tube. Fit tubes with watertight caps on the bottom and the top.

2.04 REINFORCING STEEL

A. Section 03 20 00 Concrete Reinforcing.

2.05 CONCRETE MATERIAL

A. Section 03 05 15 Portland Cement Concrete

2.06 GROUT

A. For sealing access tubes: Neat cement with a maximum water/cement ratio of 0.45.

PART 3 - EXECUTION

3.01 DRILLING

A. During drilling, make frequent checks on the plumbness, alignment, and dimensions of the shaft. All deviations exceeding the allowable tolerances shall be corrected with a procedure approved by the Resident Engineer.
B. Excavate shafts to the required depth as shown in the Contract Drawings

C. Once started, conduct the drilling in a continuous operation until excavation of the shaft is completed, except for pauses and stops as noted.

D. Pauses: Pauses during excavation except for casing splicing, tooling changes, slurry maintenance, and removal of obstructions, will not be allowed.

E. Stops

1. Stops for uncased or partially cased excavations shall not exceed 16 hours. Stops for fully cased excavations shall not exceed 65 hours. For stops exceeding the times stated above, stabilize the excavation with one or both of the following:

   a. Install casing to the depth of the excavation. The outside diameter of the casing shall not be smaller than six inches less than either the Contract Document diameter of the shaft or the actual excavated diameter of the hole, whichever is greater. Prior to removing the casing and resuming excavation, sound the annular space between the casing and the excavation. If the sounding indicates that caving has occurred, do not remove the casing. Stabilize the excavation in conformance with the approved CWP before resuming drilling.

   b. Backfill the excavation in conformance with the approved CWP. Backfill to the ground surface if the excavation is not cased, or to a minimum of five feet above the bottom of casing if the excavation is cased.

2. If slurry is used, maintain the minimum level of slurry and slurry properties during the stop.

3. During stops, stabilize the shaft excavation to prevent bottom heave, caving, head loss, and loss of ground.

F. Do not leave excavations open overnight unless cased full depth.

G. Do not operate drilling equipment from an existing bridge, unless approved by the Resident Engineer.

3.02 TEMPORARY CASING (IF APPLICABLE)

A. Provide temporary casing if required to maintain a stable excavation and facilitate construction. Provide in sufficient quantities to meet the needs of the anticipated construction method.

B. Ensure casing is watertight and clean before placement in the excavation.

C. Advance casing prior to or concurrently with excavation. Do not advance excavation ahead of casing tip farther than recommended by the geotechnical report at any time.

D. Install and remove temporary casing such that the adjacent soil outside the casing and shaft excavation for the full height of the shaft is not disturbed.

E. Use appropriate means such as a cleanout bucket or air lift to clean the bottom of the excavation of all shafts. No more than 2 inches of loose or disturbed material shall be present at the bottom of the shaft for end bearing shafts. No more than six inches of loose or disturbed material shall be present for side friction shafts. End bearing shafts shall be assumed unless otherwise noted in the Contract Drawings. Shafts specified as both side friction and end bearing shall conform to the criteria specified for end bearing shafts.
F. Allow the Resident Engineer to inspect the shaft before proceeding with construction. The bottom of the excavated shaft will be sounded with an airlift pipe, a tape with a heavy weight, or other means acceptable to the Resident Engineer.

3.03 OBSTRUCTIONS
A. When obstructions are encountered, notify the Resident Engineer promptly
B. Propose a method of removal to the Resident Engineer within 24 hours of encountering the obstruction. Once approved, proceed to remove the obstruction within 24 hours.

3.04 SLURRY (IF APPLICABLE)
A. Use slurry to maintain a stable excavation during excavation and concrete placement once water begins to enter the shaft and remain present at a depth of six inches or greater.
   1. If casing is adequately sealed into competent soils such that water does not enter the excavation, Resident Engineer may allow excavation to continue in wet soils provided the water level within the casing does not rise or exhibit flow.
B. Synthetic Slurry Technical Assistance
   1. Use synthetic slurries in conformance with the manufacturer’s written directions.
   2. If synthetic slurry is used, either a manufacturer’s representative or a Contractor’s employee trained in the use of the synthetic slurry, shall provide technical assistance for the use of the synthetic slurry, be at the site prior to introduction of the synthetic slurry into a drilled hole, and shall remain at the site during the construction and completion of a minimum of one shaft to adjust the slurry mix to the specific site conditions.
   3. After the manufacturer’s representative is no longer present at the site, ensure Contractor’s trained employee is present at the site throughout the remainder of the slurry operations to furnish technical assistance.
C. Minimum Level of Slurry in the Excavation
   1. When slurry is used to stabilize the excavation, maintain the slurry level in the excavation above the groundwater level the greatest of the following:
      a. Ten feet for water slurries
      b. Ten feet for synthetic slurries, except when a lesser dimension is specifically recommended by the slurry manufacturer for the site conditions and construction method
      c. One shaft diameter
      d. As required to provide and maintain a stable excavation
   2. Provide casing or other means as necessary to meet these requirements.
   3. Maintain the slurry level above all unstable zones a sufficient distance to prevent bottom heave, caving, or sloughing.
   4. Throughout all stops in shaft excavation operations, monitor and maintain the slurry level in the excavation the greater of the following elevations:
      a. No lower than the water level elevation outside the shaft.
b. Elevation as required to provide and maintain a stable hole.

D. Clean, recirculate, de-sand, or replace the slurry to maintain the required slurry properties.

E. Demonstrate to the satisfaction of the Resident Engineer that stable conditions are being maintained. If the Resident Engineer determines that stable conditions are not being maintained, immediately take action to stabilize the shaft. Submit a revised shaft installation plan that addresses the problem and prevents future instability. Do not continue with shaft construction until the damage that has already occurred is repaired in accordance with these Specifications, and until receiving the Resident Engineer's approval of the revised shaft installation plan.

3.05 PLACING REINFORCING

A. The reinforcing cage shall be rigidly braced to retain its configuration during handling and construction. Individual or loose bars will not be permitted.

B. Carefully position and securely fasten the reinforcing to provide the minimum clearances listed below, and to ensure that no displacement of the reinforcing steel bars occurs during placement of the concrete. Place reinforcing steel spacers at least at the quarter points around the circumference of the steel reinforcing bar cage, and at a maximum longitudinal spacing of either 2.5 times the shaft diameter or 20 feet, whichever is less.

C. Place bars as shown in the Contract Documents with minimum concrete cover as noted:

1. Shaft diameter less than or equal to 3 feet: 3 inches
2. Shaft diameter greater than 3 feet and less than 5 feet: 4 inches
3. Shaft diameter greater than 5 feet: 6 inches

D. For shafts with temporary casing within 15 feet of the bottom of shaft elevation as noted on the Contract Drawings, Resident Engineer may allow use of quarry spalls or other rock backfill below the specified bottom of shaft elevation as a means to support the reinforcing cage.

E. Shaft excavation shall not be started until the Contractor has received approval from the Resident Engineer for the reinforcing steel spacers required when the casing is to be pulled during concrete placement.

3.06 INSTALLING ACCESS TUBES FOR CROSSHOLE SONIC LOGGING

A. Install access tubes for crosshole sonic log testing in all drilled shafts except those constructed in the dry to permit access for the crosshole sonic log test probes.

B. Securely attach the access tubes to the interior of the reinforcement cage of the shaft. Place eight access tubes around the shaft inside the spiral or hoop reinforcement and three inches clear of the vertical reinforcement. If the vertical reinforcement is not bundled and each bar is not more than 1 inch in diameter, the access tubes shall be placed 2 inches clear of the vertical reinforcement. If these minimums cannot be met due to close spacing of the vertical reinforcement, then bundle the access tubes with the vertical reinforcement.

C. Install access tubes in straight alignment and as near to parallel to the vertical axis of the reinforcement cage as possible. Extend access tubes from the bottom of the reinforcement cage to at least 2 feet above either the top of the continuous concrete placement operation or the top of the shaft. Make all joints required to achieve full-length access tubes. Clear the access tubes of all debris and extraneous materials before installing the access tubes. Care
shall be taken to prevent damaging the access tubes during reinforcement cage installation operations in the shaft excavation.

D. Fill the access tubes with potable water as soon as possible after concrete placement (but no later than 1 day), and reinstall the top watertight caps.

3.07 PLACING CONCRETE

A. Conform to Section 03 30 00, Cast-In-Place Concrete

B. Place concrete immediately after completion of excavation by the Contractor and inspection by the Resident Engineer. Continue placing concrete in one operation to the top of the shaft, or as shown in the Contract Drawings. Place concrete between the upper construction joint of the shaft and the top of the shaft in the dry.

C. During concrete placement, monitor and minimize the difference in the level of concrete inside and outside the steel reinforcing cage. Conduct placement operations to maintain a maximum 1 foot differential.

D. When placing concrete in the dry, vibrate only the top 5 feet of concrete and the entire depth of the shaft-column reinforcing splice zone. If a temporary casing is used, remove it before vibration. This requirement may be waived if a temporary casing is used and removed with a vibratory hammer during the concrete placement operation. Vibration of the top 5 feet of concrete does not affect the maximum slump allowed for the concrete class specified.

E. If water is not present, deposit the concrete through the center of the reinforcement cage by a method that prevents segregation of aggregates and splashing of concrete on the reinforcement cage. Place the concrete such that the fall is vertical down the center of the shaft without hitting the sides, the steel reinforcing bars, or the steel reinforcing bar cage bracing.

F. When placing concrete underwater, use a concrete pump or tremie. A tremie shall have a hopper at the top that empties into watertight tube at least 8 inches in diameter. If a pump is used, a watertight tube shall be used with a minimum diameter of 4 inches. The discharge end of the tube on the tremie or concrete pump shall include a device to seal out water while the tube is first filled with concrete.

G. Throughout the underwater concrete placement operation, keep the discharge end of the tube submerged in the concrete at least 5 feet and enough concrete in the tube to prevent water from entering. Place concrete continuously until the work is completed, resulting in a seamless, uniform shaft. If the concrete placement operation is interrupted, the Resident Engineer may require the Contractor to prove by core drilling or other tests that the shaft contains no voids or horizontal joints. If testing reveals voids or joints, repair them or replace the shaft.

H. Before placing fresh concrete against concrete deposited in water or slurry, remove all scum, laitance, loose gravel, and sediment on the upper surface of the concrete deposited in water or slurry and chip off high spots on the upper surface of the existing concrete that would prevent the steel reinforcing bar cage from being placed in the position required by the Contract Drawings.

I. Prior to performing any crosshole sonic logging, remove the concrete at the top of the shaft down to sound concrete.

3.08 PROTECTION

A. The Contractor’s construction operation in the vicinity of a drilled shaft excavation with freshly placed concrete and curing concrete are subject to the following restrictions:
1. Do not drive piling within the distance specified and calculated in conformance with WSDOT Standard Specification.

2. Do not place or advance a casing or perform rock drilling within four shaft diameters or 30 feet of the centerline of the concreted shaft, whichever is greater, during the time period between six hours after beginning concrete placement operations and eight days after completing concrete placement operations, except after satisfying one of the following conditions:
   a. The compressive strength of the concrete in the concreted shaft shall have reached 3,000 psi. Obtain and test concrete test cylinders for this early concrete strength measurement.
   b. Implement a shaft vibration monitoring plan as follows:
      1) Furnish and install monitoring equipment in accordance with the shaft vibration monitoring plan. Locate the monitoring sensor at the concreted shaft and on a line between the concreted shaft and the construction operation within the specified boundary causing the vibration.
      2) Cease construction operations within the specified boundary when monitoring equipment detects Peak Particle velocities exceeding the following values:

<table>
<thead>
<tr>
<th>Concrete Age</th>
<th>Peak Particle Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 hours to 72 hours</td>
<td>1/4 inch per second</td>
</tr>
<tr>
<td>72 hours to 8 days</td>
<td>2 inches per second</td>
</tr>
</tbody>
</table>

3.09 REMOVING CASING (IF APPLICABLE)

A. Maintain a minimum 5-foot head of concrete as the temporary casing is removed. Completely remove all temporary casings.

3.10 FIELD QUALITY CONTROL

A. Uniform Yield Form: Complete a uniform yield form for each shaft, consistent with the sample form submitted with the CWP.

B. Slurry Sampling and Testing
   1. Mix and thoroughly hydrate synthetic slurry in slurry tanks, ponds, or storage areas.
   2. Draw sample sets from the slurry storage facility and test the samples for conformance with the appropriate specified material properties before beginning slurry placement in the drilled hole. A sample set shall be composed of samples taken at mid-height and within 2 feet of the bottom of the storage area.
   3. Sample and test all slurry in the presence of the Resident Engineer, unless otherwise directed. Record the date, time, names of the persons sampling and testing the slurry, and the results of the tests. Submit a copy of the recorded slurry test results to the Resident Engineer at the completion of each shaft, and during construction of each shaft when requested by the Resident Engineer.
   4. Take sample sets of all slurry, composed of samples taken at mid-height and within 2 feet of the bottom of the shaft, and test during drilling as necessary to verify the
control of the properties of the slurry. Take and test sample sets of synthetic slurry at
least once every 4 hours after beginning its use during each shift. Take and test
sample sets of all slurry at least once every 2 hours if the slurry is not recirculated in
the drilled hole or if the previous sample set did not have consistent specified
properties. Recirculate all slurry, or agitate with the drilling equipment, when tests
show that the sample sets do not have consistent specified properties.

5. Take sample sets of all slurry and test prior to final cleaning of the bottom of the hole
and again just prior to placing concrete. Do not start cleaning of the bottom of the
hole and placement of the concrete until tests show that the samples taken have
consistent specified properties.

C. Non-Destructive Testing of Drilled Shafts (Crosshole Sonic Logging)
1. Perform crosshole sonic log testing and analysis on all completed shafts.
2. Provide 48 hours notice to the Resident Engineer prior to the time of crosshole sonic
log testing.
3. Perform the testing after the shaft concrete has cured at least 96 hours.
4. After placing the shaft concrete and before beginning the crosshole sonic log testing
of a shaft, inspect the access tubes. Replace each access tube that the test probe
cannot pass through with a 2-inch diameter hole cored through the concrete for the
entire length of the shaft. Unless directed otherwise by the Resident Engineer, locate
cored holes approximately 6 inches inside the reinforcement and shall not damage
the shaft reinforcement. Log descriptions of inclusions and voids in cored holes and
submit a copy of the log to the Resident Engineer. Samples from cored holes shall
be preserved, identified as to location, and made available for inspection by the
Resident Engineer.

5. The Resident Engineer will determine final acceptance of each shaft, based on the
crosshole sonic log test results and analysis for the tested shafts, and will provide a
response to the Contractor within 3 working days after receiving the test results and
analysis submittal.

6. For shafts determined to be nonconforming, submit a plan for remedial action to the
Resident Engineer for approval. All modifications to the dimensions of the shafts, as
shown in the Plans, required by the remedial action plan shall be supported by
calculations and working drawings. All remedial procedures and designs shall be
submitted to the Resident Engineer for approval. Do not begin repair operations until
receiving the Resident Engineer's approval of the remedial action plan.

7. If the Resident Engineer determines that the concrete placed under slurry for a given
shaft is nonconforming, that shaft will be rejected. The placement of concrete under
slurry shall be suspended until the Contractor submits to the Resident Engineer
written changes to the methods of shaft construction needed to prevent future
structurally inadequate shafts, and receives the Resident Engineer's written approval
of the submittal.

D. Coring
1. At the Resident Engineer's request, drill a core hole in any questionable quality shaft
(as determined from crosshole sonic log testing and analysis or by observation of the
Resident Engineer) to explore the shaft condition.

2. Prior to beginning coring, submit the method and equipment used to drill and remove
cores from shaft concrete to the Resident Engineer and receives the Resident
Engineer’s written approval. The coring method and equipment shall provide for complete core recovery and shall minimize abrasion and erosion of the core.

E. Dewater all access tubes and cored holes and fill with grout after tests are completed. Use grout tubes that extend to the bottom of the tube or hole or into the grout already placed.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for cleaning and repairing existing slurry diaphragm walls constructed but not exposed in previous contracts.

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 74 00, Cleaning and Waste Management
2. Section 03 05 15, Portland Cement Concrete.
3. Section 03 30 00, Cast-in-Place Concrete.
4. Section 03 64 23, Epoxy Injection Grouting
5. Section 07 10 00, Waterproofing and Seepage Management.

1.02 DEFINITIONS
A. Slurry Wall: Reinforced concrete diaphragm wall panel constructed by the slurry panel method.

B. Theoretical Excavation Line: Theoretical line of excavation inside of which no earth or surrounding ground protrudes.

1.03 TOLERANCES
A. This Section of the Specifications establishes the minimum tolerances for the exposed surfaces of the completed and repaired slurry wall. The Contractor is responsible for developing the appropriate practices in order to meet these requirements, subject to concurrence of the Resident Engineer.

B. Tolerances
1. Slurry Walls:
   a. Top elevation of panel: Within plus or minus 0.1 foot.
   b. Location of panel at grade: Within plus or minus 0.1 foot of theoretical or plan location.
   c. Vertical tolerance: within 0.5 percent of the depth from theoretical vertical plane. Check verticality of the wall panels every 50 feet of depth in each panel as a minimum.

2. Formed Recesses: plus or minus three inches of the indicated location.
1.04 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Product Data: For all manufactured products submit:
      1. Manufacturer’s product data.
      2. Manufacturer’s written instructions for storage, handling and installation.

PART 2 - PRODUCTS

2.01 MATERIALS
   A. Cast-in-place Concrete
      1. Proportion mixes per Section 03 05 15, Portland Cement Concrete.
   B. Reinforcement
      1. Steel Reinforcement: as specified in Section 03 20 00, Concrete Reinforcing.
      2. Fiberglass Reinforcement: as specified in Section 03 49 00, Glass-Fiber-Reinforced Concrete.
   C. Repair Grout
      1. Proportion per Section 03 30 00, Cast-in-Place Concrete; or 03 64 23, Epoxy Injection Grouting.

PART 3 - EXECUTION

3.01 SLURRY WALL CLEANING
   A. Top-of-Wall Preparation
      1. Remove by chipping concrete above final top-of-wall elevation.
      2. Clean top of wall as described under “Slurry Wall Cleaning” below.
      3. Prepare mechanical splices as described under “Mechanical Splice Preparation.”
   B. Formed Recess Preparation
      1. Remove recess formwork to fully expose concrete surface below.
      2. Roughen exposed surface as required to provide a full amplitude of approximately 1/4 inch.
      3. Clean formed recess as described under “Slurry Wall Cleaning” below.
      4. Prepare mechanical splices as described under “Mechanical Splice Preparation.”
   C. Mechanical Splice Preparation
      1. Prepare mechanical splices as they are exposed.
2. Verify mechanical splice size and condition by installing a prepared test bar. Confirm that the test bar can be installed in splice in conformance with the manufacturer’s written directions. Notify the Resident Engineer of any nonconforming splices.

3. Protect mechanical splices with plastic covers until used.

D. Temporary Bracing Connection Demolition

1. Demolish temporary bracing connections to within 1 inch of the exposed face of embedded plate.

E. Slurry Wall Cleaning

1. Clean exposed surfaces with either high pressure water or steel rotary brushes after excavation.

3.02 SLURRY WALL REPAIRING

A. Remove any concrete that encroaches past the theoretical excavation line, taking into account allowable tolerances.

B. Repair any flaws or imperfections that could damage or interfere with the membrane waterproofing system.

C. Remove and repair any zones of weak concrete.

D. Repair surface defects in accordance with Section 03 30 00, Cast-in-Place Concrete.

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
      b. Standard Plans for Municipal Construction
      a. ASTM D2922 Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. List source location of materials 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. Uniformly spread base material upon the prepared subgrade to the depth, width, and cross-
      section shown in the Contract Drawings or as referenced in a COS Standard Plan.
   B. Construct in accordance with COS Standard Specifications Section 4-04.3.

3.04 FIELD QUALITY CONTROL
   A. Test for compliance with specified requirements for density and compaction as 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. 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 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 (SDOT):
      a. 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).
E. Anti-stripping additive: COS Standard Specification Section 9-02.4

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. Parking Lot paving: Follow the requirements of the “Structural application-minor quantity” as defined in the COS Standard Specifications Section 5-04.3(6).
D. Sidewalk paving: follow the requirements of the “Non-structural application” as defined in the COS Standard Specifications Section 5-04.3(6).
E. 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 in accordance with COS Standard Specification Section 9-03.6(3).
3. Aggregates for Hot Mix Asphalt: Test Requirements in accordance with 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 is to be used as a base for one or more courses of new asphalt concrete, the entire surface of the pavement must first be cleaned.

2. Remove all fatty asphalt patched, 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 all patched areas.

3. Apply Tack Coat to all paved surfaces on which any course of HMA is to be placed or abutted in accordance with 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 COS Directors Rule: 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). Note thickness of asphalt tested for each testing location.

B. Compaction and Density for ATB in accordance with 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.

3.04 MAINTENANCE OF PAVEMENT

A. 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.

B. Maintain finished pavement in finished clean condition until the work is accepted by the Resident Engineer.

END OF SECTION
SECTION 32 12 83
DECOMPOSED GRANITE PAVEMENT

PART 1 - GENERAL

1.01 SUMMARY
A. This Section specifies materials and installation of Decomposed Granite (DG) Pavement.
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 56 39, Temporary Tree and Plant Protection.
   2. Section 32 11 23, Aggregate Base Courses.

1.02 REFERENCES
A. This Section incorporates by reference the latest revisions of the following documents.
      c. ASTM D448, Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
      d. ASTM D698, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 5.5-lb Rammer and 12 in. drop.
      e. ASTM D1557, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 10-lb Rammer and 18 in. drop.
      g. ASTM D4254, Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density.

1.03 PERFORMANCE REQUIREMENTS
A. Perform gradation of decomposed granite material or 3/8 inch or 1/4 inch minus crushed aggregate in accordance with ASTM C136 – Method for Sieve Analysis for Fine and Course.

1.04 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Product Data: Manufacturer’s published literature for Decomposed Granite and each product specified.

C. Samples:
   1. Decomposed Granite: Two 1 pound bags in specified size, color, and texture showing conformance to selection and specified requirements.
   2. Stabilizer: Two 1/2 pound bags.
   3. Products Data: For each product specified. Submit a 5 pound sample and sieve analysis for grading of decomposed granite or crushed 3/8 inch or 1/4 inch minus aggregate to be sent to Stabilizer Solutions, Inc. prior to any construction – (allow 2 week turn-around). Must be approved by Resident Engineer.

D. Qualifications: Installer and fabricator.

E. Certification: Written statement signed by Installer’s Representative and Contractor that Decomposed Granite, binder, and other accessories have been provided as specified, or where different, as accepted by Resident Engineer.

F. Shop Drawings: Show details of installation, including plans and sections.

G. Maintenance Stock:
   1. Submit maintenance stock to Resident Engineer. Obtain signed receipt.
   2. DG Pavement: Minimum 1 percent of each size and color, palletized or contained in protective containers, clean, and labeled as to manufacturer and product.

1.05 QUALITY ASSURANCE

A. Source Quality Control:
   1. Obtain stone from single quarry for Decomposed Granite (DG) as specified by this Section and as accepted by Resident Engineer.

B. Installation: Performed only by skilled Contractors with satisfactory record of performance on landscaping or paving projects of comparable size and quality.
   1. Installer to provide evidence to indicate successful experience in providing decomposed granite or crushed 3/8 inch or 1/4 inch minus aggregate paving containing Stabilizer binder additive or ability to follow installation instructions.

C. Mock-up:
   1. Construct approximately 100 square foot mock-up of DG Pavement illustrating complete system including one Metal Tree Grate.
   2. Include setting method and paving.
   3. Verify that binder sealers, cleaners, and other treatments will not change color or physical characteristics of Decomposed Granite.
   4. Do not incorporate Resident Engineer accepted mock-ups into Work of this Contract.
5. Protect accepted mock-ups as standard of quality for work of this Section throughout duration of construction.

D. Pre-installation Conference:

1. Attendance: Resident Engineer, installer, distributor’s representative, and those requested to attend.

2. Meeting Time: Minimum 1 week prior to beginning work of related Sections affecting work of this Section.

3. Location: Project Site.

1.06 PROJECT CONDITIONS

A. Review installation procedures and coordinate DG Pavement work with other work affected.

B. All hard surface paving adjacent to DG Pavement areas, including concrete walks and asphalt paving must be completed prior to installation of DG Pavement.

C. Cold weather:

1. Do not use frozen materials, or materials mixed or coated with ice or frost.

2. Do not build on frozen work or wet, saturated or muddy subgrade.

D. Protect partially completed DG Pavement against damage from other construction traffic when work is in progress. Any barricades constructed must still be accessible by emergency and fire equipment during and after installation.

E. Protect adjacent work from damage during DG Pavement installation.

1.07 DELIVERY AND STORAGE OF MATERIALS

A. Packaged Materials: Deliver packaged materials in clearly marked containers showing net weight, guaranteed analysis and name of manufacturer. Specified requirements for packaged materials apply to bulk shipments. Protect materials from deterioration during delivery and during storage at site.

1.08 COORDINATION

A. Coordination with work of other Sections.

1.09 WARRANTY

A. General Warranty: The special warranty specified in this Article shall not deprive the Resident Engineer of other rights provided under other provisions of the Contract Documents and shall be in addition to, and run concurrent with, other warranties made by the Contractor under requirements of the Contract Documents.

B. Special Warranty: Submit a written warranty executed by the installer agreeing to repair or replace components of stabilized surfacing that fail in materials or workmanship within the specified warranty period. Stabilizer Solutions, Inc. does not warrant imitation “Stabilizer” purchased from a non-approved Stabilizer Solutions, Inc. licensee. Failures include, but are not limited to, the following:
1. Premature wear and tear, provided that the material is maintained in accordance with manufacturer’s written maintenance instructions.

2. Failure of system to meet performance requirements.

C. Warranty Period: Provide warranty for performance of product. Warranty installation of product for the time of 1 year from completion.

D. Provide, for a period of 60 days, unconditional maintenance and repairs as required.

PART 2 - PRODUCTS

2.01 AVAILABILITY

A. Stabilizer for crushed stone surfaces provided by the following manufacturer:

1. Stabilizer Solutions, Inc., 33 South 28th St., Phoenix, AZ 85034; phone (602) 225-5900, (800) 336-2468; fax (602) 225-5902; website stabilizersolutions.com; email info@stabilizersolutions.com.

2. Or accepted equal.

B. Decomposed Granite to be provided by 1 of the following manufacturers:

1. Lakeview Quarry SE, 525 S. Front Street, Seattle, WA 98108.

2. Manufacturers Minerals, Renton, WA.

3. Or accepted equal.

2.02 MATERIALS

A. Decomposed Granite or 3/8 inch or 1/4 inch crushed aggregate screenings:

1. Crushed Stone Sieve Analysis Percentage of Weight Passing a Square Mesh Sieve AASHTO T11-82 and T27-82.

2. 1/4 inch MINUS AGGREGATE GRADATION

<table>
<thead>
<tr>
<th>U.S. Sieve No.</th>
<th>Percent Passing by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td># 3/8 inch</td>
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<tr>
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<tr>
<td># 100</td>
<td>15 – 20</td>
</tr>
<tr>
<td># 200 to</td>
<td>10 – 15</td>
</tr>
</tbody>
</table>

3. Acceptable local supplier list to be provided by Resident Engineer.

B. Stabilized Binder:

1. Stabilized Binder: StaLok W/A

2. Or accepted equal.

C. Base Course: See Specification Section 32 11 23, Aggregate Base Courses.
2.03 EXCESS MATERIALS
   A. Provide Resident Engineer with the following excess materials for use in future decomposed granite or 3/8 inch or 1/4 inch minus crushed aggregate paving repair: Five 40 to 50 pound bags of the aggregate paving blended with proper amount of Stabilizer.

PART 3 - EXECUTION

3.01 INSPECTION
   A. Resident Engineer to examine subgrade and base course installed conditions for improperly compacted trenches, debris, and improper gradients. Do not start DG Pavement installation until unsatisfactory conditions are corrected.
   B. Installation constitutes acceptance of existing conditions and responsibility for satisfactory performance. If existing conditions are found unsatisfactory, contact Resident Engineer for resolution.

3.02 PREPARATION
   A. Refer to Section 01 56 39, Temporary Tree and Plant Protection for construction within CRZ areas.
   B. Place base course material over prepared subbase to grades shown on plans, in lifts not to exceed 6 inches, compacting each lift separately to 95 percent Modified Proctor.

3.03 INSTALLATION
   A. Conform to manufacturer’s instructions and provisions of Contract Documents.

3.04 INSTALLATION TOLERANCES
   A. Variation in Surface Plane: Maximum 1/8 inch in 10 foot, 1/4 inch in 20 foot, and 3/8 inch total.
   B. Variation in Alignment of Adjacent Paving Surfaces: Maximum 1/16 inch difference.

3.05 ADJUSTING
   A. Repair or replace work not conforming to mock-up and other provisions of Contract Documents.

3.06 PROTECTION
   A. DG Pavement must be protected from all vehicle and foot traffic during installation.

3.07 CLEANING
   A. Remove and replace segments of DG Pavement where damaged, reinstalling as specified, so no evidence of replacement is apparent.
   B. Perform cleaning during the installation of work and upon completion of the work. Remove all excess materials, debris, and equipment from site. Repair any damage to adjacent materials and surfaces resulting from installation of this work.
PART 4 - BLENDING STABILIZER

4.01 BLENDING
A. Call manufacturer for exact blend of Stabilizer and DG. Blend approximately 12 to 16 pounds (call manufacturer for exact blend) of Stabilizer per 1 ton of decomposed granite or crushed 3/8 inch or 1/4 inch minus aggregate screenings. It is critical that Stabilizer be thoroughly and uniformly mixed throughout decomposed granite or crushed 1/4 inch or 3/8 inch minus aggregate screenings. Bucket blending is not acceptable. Blending with a rake and/or shovel is not acceptable. Blend material dry as water will make the material hard.

4.02 PLACEMENT
A. After pre-blending, place the Stabilized decomposed aggregate or 3/8 inch or 1/4 inch crushed aggregate screenings on prepared sub-grade. Level to desired grade and cross section.

B. Depth of pathways: 3 inches for heavy foot traffic and light vehicles.

4.03 WATERING
A. Water heavily for full-depth moisture penetration of the Stabilized pathway profile. Water activates Stabilizer. To achieve saturation of Stabilized pathway profile, 25 to 45 gallons of water per 1 ton must be applied. During water application randomly test for depth using a probing device, which reaches full depth.

4.04 COMPACTION
A. Upon thorough moisture penetration, compact aggregate screenings to 85 percent relative compaction by equipment such as a 2 to 4 ton double drum roller or a 1,000 pound single drum roller. The roller size will depend on the depth of the DG Pavement. Do not use a vibratory plate compactor. Do not begin compaction for 6 hours after placement and up to 48 hours.

B. Take care in compacting decomposed granite or crushed 3/8 inch or 1/4 inch minus aggregate screenings when adjacent to planting and irrigation systems. Hand tamping with 8 inches or 10 inches hand tamp recommended.

4.05 INSPECTION
A. Finished surface of DG Pavement shall be smooth, uniform and solid. There shall be no evidence of cracking. Cured and compacted pavement shall be firm throughout profile with no spongy areas. Loose material will not be present on the surface after installation, but may appear after use and according to environmental conditions. Pavement should remain stable underneath the loose granite on top. It is a “natural” looking pavement, yet stable throughout. Any significant irregularities in pavement surface shall be repaired to the uniformity of entire installation.

4.06 MAINTENANCE
A. Remove debris, such as paper, grass clippings, leaves or other organic material by mechanically blowing or hand raking the surface as needed. Any plowing program required during winter months shall involve the use of a rubber baffle on the plow blade or wheels on the plow that lifts the blade 1/4 inch off the paving surface.
B. During the first year, a minor amount of loose aggregate will appear on the paving surface (1/16 inch to 1/4 inch). If this material exceeds a 1/4 inch, redistribute the material over the entire surface. Water thoroughly to the depth of 1 inch. Compact with a power roller of no less than 1000 pounds. This process should be repeated as needed.

4.07 REPAIRS

A. Excavate damaged area to the depth of the stabilized aggregate and square off sidewalls.

B. If area is dry, moisten damaged portion lightly.

C. Pre-bend the dry required amount of stabilizer powder with the proper amount of aggregate in a concrete mixer.

D. Add water to the pre-blended aggregate and stabilizer. Thoroughly moisten mix with 25 to 45 gallons per 1 ton of pre-blended material or to approximately 10 percent moisture content.

E. Apply moistened pre-blended aggregate to excavated area to finish grade.

F. Compact with an 8 inches to 10 inches hand tamp or 250- to 300-pound roller. Keep traffic off areas for 12 to 48 hours after repair has been completed.

END OF SECTION
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SECTION 32 13 13

CONCRETE PAVING

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 (SDOT):
   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. Submit mix design to the Resident Engineer including 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 apply:

1. Concrete mix for arterial pavement: Class 6.5 (1-1/2)
2. Concrete mix for residential streets and alleys: Class 6 (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 per Section 31 20 00, Earth Moving.

B. Construct Aggregate Base Course surfacing where indicated in accordance with Section 32 11 23, Aggregate Base Courses.
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.

4. Construct portland cement concrete driveways in accordance with COS Standard Specifications Section 8-19.3.

5. Concrete 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
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SECTION 32 14 13
PRECAST CONCRETE UNIT PAVING

PART 1 - GENERAL

1.01 SUMMARY
   A. This Section includes specifications for removing and storing existing unit paving for reuse, and installing new and salvaged Unit Pavers.
   B. Existing precast concrete unit pavers are located in three existing plazas on the west side of Husky Stadium.
   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 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.
         a. ASTM C33, Specification for Concrete Aggregates
         c. ASTM C140, Standard Test Methods for Sampling and Testing Masonry Units and Related Units
         d. ASTM C144, Standard Specification for Aggregate for Masonry Mortar
         e. ASTM C936, Standard Specification for Solid Concrete Interlocking Paving Units
      2. City of Seattle (COS):
         a. Standard Specifications for Road, Bridge, and Municipal Construction

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Layout Drawings: Submit layout drawings showing typical installation of pavers, including layout dimensions, field cutting and coordination of pavers with below grade vaults and utility lids.
   C. Product data for the following products:
1. Precast Concrete Unit Pavers

D. Samples:

1. Precast Pavers: Submit three sets of precast concrete paver samples for verification purposes. Submit sets of full size units for each of the unit paver types indicated showing color, texture and pattern specified and the full range of variations expected in these characteristics.

E. Qualification data for firms and persons specified in Article 1.04 herein to demonstrate their capabilities and experience. Include list of completed projects with project names, addresses, names of architects and owners, plus other information specified.

1.04 QUALITY ASSURANCE

A. Manufacturers Qualifications: Minimum of 5 years experience in the manufacturing of precast concrete units of quality specified.

B. Installer Qualifications: Engage an experienced installer who has successfully completed unit paver installations similar in material, design, and extent to that indicated for the Contract.

C. Single Source Responsibility: Obtain each color, type and variety of unit pavers from a single source with resources to provide products and materials of consistent quality in appearance and physical properties without delaying progress of the work.

D. Tolerance: Fabrication Tolerances: Variations no more than plus or minus 1/16 inch in width, height, length, thickness, concave or convex deflection.

E. Acceptability or Appearance: The following list of finish defects are unacceptable. Replace these defects with a new unit at no additional cost to Sound Transit.

1. Pavers not being within the approved color range
2. Non-uniformity of surface texture.
3. Foreign material embedded in the face.
4. Shrinkage cracks.
5. Ragged or irregular edges. Minor defects incidental to the usual method of manufacturer or slight chipping resulting from handling and delivery may be acceptable to the Resident Engineer provided such defects are minor in scope and do not affect the overall quality and appearance of the work.

F. Extra Stock: Furnish extra stock of quantity equal to 0.5 percent of amount installed, in full-size units, for each type, color, size and finish of tile to location specified by Resident Engineer.

1.05 DELIVERY, STORAGE AND HANDLING

A. Deliver precast pavers on wood pallets, covered with non-staining waterproof membrane; allow air to circulate around precast units.

B. Handle precast units to prevent chipping, breakage, soiling or other damage. Do not use pinch or wrecking bars without protecting edges of precast units with wood or other rigid materials. Lift with wide-belt type slings wherever possible; do not use wire ropes or ropes containing tar or other substances that might cause staining. If required, use wood rollers and provide cushion at end or wood slides.
1.06 PROJECT CONDITIONS

A. Prior to commencing work on the site, record existing conditions of the unit paver areas via a video or picture record. Include any areas of pavers that may be driven on by construction equipment and areas where utility trenching will occur.

B. Review installation procedures, and coordinate with other work, and others whose work will be affected by the precast units work.

C. Cold Weather Protection: Do not use frozen materials or materials mixed or coated with ice or frost. Do not build on frozen subgrade or setting beds. Remove and replace unit paver work damaged by frost or freezing.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Bedding Sand: gradation conforming to ASTM C33. Do not use Mason sand.

B. Joint filling Sand: Mason Sand conforming to ASTM C144 and the following gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>ASTM C144 Natural Sand</th>
<th>ASTM C144 Manufactured Sand</th>
</tr>
</thead>
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<td>100</td>
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<tr>
<td>No. 8</td>
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</tr>
<tr>
<td>No. 200</td>
<td>0</td>
<td>0 to 10</td>
</tr>
</tbody>
</table>

C. Precast Concrete Pavers

1. Type and Manufacturer: Match existing pavers in the area of work for dimensions and color.
   a. Color: Match color to existing pavers.
   b. Dimensions: Match existing dimensions of 4-1/2"x9”x3-1/8" for UNI-Décor® style units.

2. Physical Properties:
   a. General: Meet the requirements of ASTM C936.
b. Compressive Strength: Minimum 7,000 pounds per square inch (psi) at 28 days when tested in accordance with ASTM C140.

c. Water Absorption: Maximum of 5 percent when tested in accordance with ASTM C140.

d. Freeze/Thaw: Ensure pavers meet the freeze/thaw tests in accordance with Section 8 of ASTM C 67. Ensure specimens when tested have no breakage and not greater than 1 percent loss in dry weight of any individual unit when subjected to 50 cycles of freezing and thawing.

D. Geotextile: Conform to City of Seattle Standard Specification Section 9-37.2, Table 3, Separation.

PART 3 - EXECUTION

3.01 PREPARATION

A. Remove and replace unit pavers damaged due to construction activities or construction vehicle movements.

B. Prepare subgrade for surfacing in accordance with Section 31 20 00, Earth Moving.

3.02 INSTALLATION

A. General

1. Do not use precast units with chips, cracks, voids, stains, or other defects that might be visible in the finished work. Before setting precast units, examine units for conformance with specified fabrication tolerances and appearance standards. Reject units not meeting requirements.

2. Use power driven masonry saws for cutting of pavers; provide clean, sharp unchipped edges; cut to provide pattern indicated and to fit adjoining work neatly; accurately form corners. Cut straight to create a 90 degrees angle to the top/bottom of the paver. Cut the top edges of all cut pavers that abut other pavers to maintain the 1/4-inch chamfer edges. Use full units without cutting wherever possible.

B. Place Aggregate Base Course in accordance with Section 32 11 23, Aggregate Base Courses.

C. Call for an inspection by the Resident Engineer and obtain written acceptance of the prepared base course before proceeding with the placement of sand bedding.

D. Geotextile: Install geotextile fabric between the aggregate base course and sand bedding.

E. Sand Bedding:

1. Spread bedding sand uniformly over the working area and screed and level to the lines and thicknesses indicated on the Contract Drawings. Screed and level the sand bed to create a loose surface. Remove, replace, and re-screed any area of bedding sand which becomes un-uniformly compacted by any means (including foot prints).

F. Paver Block Placement:
1. Place pavers on the screeded sand from the low side to the high side. Match lay pattern to existing pavers. Leave a 1/8 inch joint space between pavers.

G. Compaction:

1. Use a vibrating plate compactor to consolidate the pavers and sand to the finished grade.

2. Continue compaction until the level of the pavers has stabilized.

3. Use a plate compactor that has a high frequency, low amplitude vibrator with a plate surface of at least 2-1/2 square feet.

4. Compact pavers at the completion of each day’s laying.

5. Remove and replace pavers that are cracked or structurally damaged during compaction at no expense to Sound Transit.

H. Filling joints:

1. After compaction, sweep joint filling sand into the joints. Sweep away excess sand from the top surface prior to vibrating. Run a vibrating plate compactor over the pavers to work the sand into the joints. Continue the process of sweeping sand into the joints and vibrating until the joints do not accept any more sand. Repeat sand addition and vibration on a weekly basis until the joints are filled and do not accept more sand. Do not use water to wash sand into the joints.

3.03 FIELD QUALITY CONTROL

1. Vertical Installation Tolerance: Not exceeding 1/8 inch in 10 feet in any direction from level or slopes indicated when tested with a 10-foot straightedge.

2. The vertical installation tolerances also apply at the transition between existing and newly installed pavers.

3. Remove and reset pavers or paver areas which do not meet these tolerances at no additional cost to Sound Transit.

END OF SECTION
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SECTION 32 14 13.19

PERMEABLE INTERLOCKING CONCRETE PAVEMENT

PART 1 - GENERAL

1.01 SUMMARY

A. Section Includes:
   1. Permeable interlocking concrete pavers.
   2. Crushed stone bedding material.
   3. Open-graded subbase aggregate.
   4. Open-graded base aggregate.
   6. Edge restraints.
   7. Geotextiles.

B. Related Sections:
   1. Section 01 33 00, Submittal Procedures.
   2. Section 01 78 23, Operation and Maintenance Data.
   3. Section 32 13 13, Concrete Paving.
   4. Section 32 90 00, Planting.

1.02 REFERENCES

A. American Society for Testing and Materials International (ASTM):
   1. ASTM C67, Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.
   5. ASTM D448, Standard Classification for Sizes of Aggregate for Road and Bridge Construction.
   7. ASTM C979, Specification for Pigments for Integrally Colored Concrete.
8. ASTM D698, Test Methods for Moisture Density Relations of Soil and Soil Aggregate Mixtures Using a 5.5-lb Rammer and 12 inch drop.


B. Interlocking Concrete Pavement Institute (ICPI):

1. Permeable Interlocking Concrete Pavement manual.

1.03 SUBMITTALS

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

B. Manufacturer’s drawing and details: Indicate perimeter conditions, junction with other materials, expansion and control joints, paver layout, patterns, installation and setting details. Indicate layout, pattern, and relationship of paving joints to fixtures and project formed details.

C. Sieve analysis of aggregates for base and bedding materials in accordance with ASTM C136.

D. Soils report indicating density test reports, classification, and infiltration rate measured on-site under compacted conditions, and suitability for the intended project.

E. Erosion and sediment control plan.

F. Stormwater management (quality and quantity) calculations.

G. Permeable concrete pavers:

1. Manufacturer’s product catalog sheets with specifications.

2. Four representative full-size samples of each paver type, thickness, color, and finish. Submit samples indicating the range of color expected in the finished installation.

3. Accepted samples become the standard of acceptance for the work of this Section.

4. Laboratory test reports certifying compliance of the concrete pavers with ASTM C936.

5. Manufacturer’s material safety data sheets for the safe handling of the specified materials and products.

H. Paver Installation Subcontractor:

1. A copy of Subcontractor’s current certificate from the Interlocking Concrete Pavement Institute Concrete Paver Installer Certification program.
2. Job references from projects of a similar size and complexity. Provide resident engineer/general contractor names, postal address, phone, fax, and email address.

1.04 QUALITY ASSURANCE

A. Paver Installation Subcontractor Qualifications:
   1. Utilize an installer having successfully completed concrete paver installation similar in design, material, and extent indicated on this project.
   2. Utilize an installer holding a current certificate from the Interlocking Concrete Pavement Institute Concrete Paver Installer Certification program.

B. Regulatory Requirements and Approvals: [Specify applicable licensing, bonding or other requirements of regulatory agencies.]

C. Mock-Ups:
   1. Install a 10-foot by 10-foot paver area.
   2. Use this area to determine surcharge of the bedding sand layer, joint sizes, lines, laying pattern(s), color(s) and texture of the job.
   3. This area will be used as the standard by which the work will be judged.
   4. Subject to acceptance by Resident Engineer, mock-up may be retained as part of finished work.
   5. If mock-up is not retained, remove and properly dispose of mock-up.

1.05 DELIVERY, STORAGE, AND HANDLING

A. General: Comply with Section 01 60 00, Product Requirement.

B. Comply with manufacturer’s ordering instructions and lead-time requirements to avoid construction delays.

C. Delivery: Deliver materials in manufacturer’s original, unopened, undamaged container packaging with identification tags intact.
   1. Coordinate delivery and paving schedule to minimize interference with normal use of buildings adjacent to paving.
   2. Deliver concrete pavers to the site in steel banded, plastic banded, or plastic wrapped cubes capable of transfer by forklift or clamp lift.
   3. Unload pavers at job site in such a manner that no damage occurs to the product or existing construction

D. Storage and Protection: Store materials in protected area such that they are kept free from mud, dirt, and other foreign materials.

1.06 ENVIRONMENTAL REQUIREMENTS

A. Do not install in rain or snow.

B. Do not install frozen bedding materials.
1.07 MAINTENANCE

A. Extra materials: Provide 5 percent additional material for use by Resident Engineer for maintenance and repair.

B. Pavers shall be from the same production run as installed materials.

PART 2 - PRODUCTS

2.01 PERMEABLE INTERLOCKING CONCRETE PAVERS

A. Manufacturer: Mutual Materials

B. Permeable Interlocking Concrete Paver Units:
   1. Paver Type: Eco-Prioria or approved equal.
      b. Standard color and finish.
      c. Size: 7-3/4 inches x 7-3/4 inches x 3-1/8 inches thick.
   2. Average Compressive Strength (ASTM C140): 8000 psi with no individual unit under 7200 psi.
   3. Average Water Absorption (ASTM C140): 5 percent with no unit greater than 7 percent.
   4. Freeze/Thaw Resistance (ASTM C67): Resistant to fifty freeze/thaw cycles with no greater than 1 percent loss of material. Freeze-thaw testing requirements shall be waived for applications not exposed to freezing conditions.

2.02 PRODUCT SUBSTITUTIONS

A. Substitutions: No substitutions permitted.

2.03 CRUSHED STONE FILLER, BEDDING, BASE AND SUBBASE

A. Crushed stone with 90 percent fractured faces, LA Abrasion < 40 in accordance with ASTM C131, minimum CBR of 80 percent in accordance with ASTM D1883.

B. Do not use rounded river gravel.

C. All stone materials shall be washed with less than 1 percent passing the No. 200 sieve.

D. Joint/opening filler, bedding, base and subbase: conforming to ASTM D448 gradation as shown in Tables 1, 2 and 3 below:

<table>
<thead>
<tr>
<th>TABLE 1</th>
</tr>
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<tbody>
<tr>
<td><strong>Grading Requirements for ASTM No. 8</strong></td>
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<tr>
<td><strong>Bedding and Joint/Opening Filler</strong></td>
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<tr>
<td><strong>Sieve Size</strong></td>
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<td>1/2 in</td>
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### TABLE 2

Grading Requirements for ASTM No. 57 Base

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<th>Sieve Size</th>
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<tr>
<td>No. 8</td>
<td>0 to 5</td>
</tr>
</tbody>
</table>

### TABLE 3

Grading Requirements for ASTM No. 2 Subbase

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 in</td>
<td>100</td>
</tr>
<tr>
<td>2-1/2 in</td>
<td>90 to 100</td>
</tr>
<tr>
<td>2 in</td>
<td>35 to 70</td>
</tr>
<tr>
<td>1-1/2 in</td>
<td>0 to 15</td>
</tr>
<tr>
<td>3/4 in</td>
<td>0 to 5</td>
</tr>
</tbody>
</table>

E. Gradation criteria for the bedding and base:

1. \( D_{15} \) base stone / \( D_{50} \) bedding stone < 5.
2. \( D_{50} \) base stone / \( D_{50} \) bedding stone > 2.

### 2.04 ACCESSORIES

A. Provide the following accessory materials:

1. Edge Restraints
2. Geotextile Fabric

### PART 3 - EXECUTION

#### 3.01 EXAMINATION

A. Acceptance of Site Verification of Conditions:

1. Contractor shall inspect, accept and certify in writing to the paver installation Subcontractor that site conditions meet specifications for the following items prior to installation of interlocking concrete pavers.
   
a. Verify that subgrade preparation, compacted density and elevations conform to specified requirements.
b. Provide written density test results for soil subgrade to the Resident Engineer, Contractor and paver installation Subcontractor.

c. Verify location, type, and elevations of edge restraints, utility structures, and drainage pipes and inlets.

2. Do not proceed with installation of bedding and interlocking concrete pavers until subgrade soil conditions are corrected by the Contractor or designated Subcontractor.

3.02 PREPARATION

A. Refer to Section 01 56 39, Temporary Tree and Plant Protection for construction within CRZ areas.

B. Verify that the soil subgrade is free from standing water.

C. Stockpile joint/opening filler, base and subbase materials such that they are free from standing water, uniformly graded, free of any organic material or sediment, debris, and ready for placement.

D. Edge Restraint Preparation:
   1. Install edge restraints at the elevations indicated in accordance the Contract Drawings.

3.03 INSTALLATION

A. General
   1. Any excess thickness of soil applied over the excavated soil subgrade to trap sediment from adjacent construction activities shall be removed before application of the geotextile and subbase materials.

   2. Keep area where pavement is to be constructed free from sediment during entire job. Geotextiles Base and bedding materials contaminated with sediment shall be removed and replaced with clean materials.

   3. Do not damage drainpipes, overflow pipes, observation wells, or any inlets and other drainage appurtenances during installation. Report any damage immediately to the Resident Engineer.

B. Geotextiles
   1. Place on bottom and sides of soil subgrade. Secure in place to prevent wrinkling from vehicle tires and tracks.

   2. Overlap a minimum of 24 inches in the direction of drainage.

C. Open-graded subbase and base
   1. Moisten, spread and compact the No. 2 subbase in 4 to 6 inch lifts without wrinkling or folding the geotextile. Place subbase to protect geotextile from wrinkling under equipment tires and tracks.

   2. For each lift, make at least two passes in the vibratory mode then at least two in the static mode with a minimum 10-ton vibratory roller until there is no visible movement of the No. 2 stone. Do not crush aggregate with the roller.
3. The surface tolerance of the compacted No. 2 subbase shall be 3/4 inch over a 10-foot straightedge.

4. Moisten, spread and compact No. 57 base in 4 to 6 inch lifts over the compacted No. 2 subbase with a minimum 10-ton vibratory roller until there is no visible movement of the No. 57 stone. Do not crush aggregate with the roller.

5. The surface tolerance the compacted No. 57 base should not deviate more than 1/2 inch over a 10-foot straightedge.

D. Bedding layer

1. Moisten, spread and compact the No. 8 bedding material. Compact with a minimum 10-ton static roller. Make at least 4 passes. No visible movement should occur in the base material when compaction is complete. Do not crush aggregate with the roller.

2. The surface tolerance of the compacted surface should not deviate more than 1/2 inch over a 10-foot straightedge.

E. Permeable interlocking concrete pavers and joint/opening fill material

1. Lay the pavers in the pattern(s) and joint widths shown on the Contract Drawings. Maintain straight pattern lines.

2. Fill gaps at the edges of the paved area with cut units. Cut pavers subject to tire traffic shall be no smaller than 1/3 of a whole unit.

3. Cut pavers to be placed along the edges with a double-bladed splitter or masonry saw.

4. Compact and seat the pavers into the bedding material using a low-amplitude, 75-90 Hz plate compactor capable of at least 5,000 lbs. centrifugal compaction force. This will require at least two passes with the plate compactor.

5. Do not compact within 6 feet of the unrestrained edges of the paving units.

6. Fill the openings and joints with No. 8 stone.

7. Remove excess aggregate by sweeping pavers clean.

8. Compact the pavers again, vibrating the aggregate into the openings. Apply additional aggregate to the openings and joints, filling them completely. Remove excess aggregate by sweeping and compact the pavers. This will require at least two passes with the plate compactor.

9. All pavers within 6 feet of the laying face must be left fully compacted at the completion of each day.

10. The final surface tolerance of compacted pavers shall not deviate more than ±3/8 inch under a 10 feet long straightedge.

11. The surface elevation of pavers shall be 1/8 to 1/4 inch above adjacent drainage inlets, concrete collars or channels.

3.04 FIELD QUALITY CONTROL

A. After sweeping the surface clean, check final elevations for conformance to the drawings.
B. Lippage: No greater than 1/8 inch difference in height between adjacent pavers.

C. The surface elevation of pavers shall be 1/8 to 1/4 inch above adjacent drainage inlets, concrete collars or channels.

3.05 PROTECTION

A. After work in this section is complete, the Contractor shall be responsible for protecting work from sediment deposition and damage due to subsequent construction activity on the site.

END OF SECTION
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.

   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 on UW property: Minimum 28-day compressive strength of 3,000 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 410C curb and Cement Concrete Traffic Curb: 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: #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 a strength of 2500 psi. Leave protection measures in place for at least 72 hours.

C. Type 410C Curb and Cement Concrete Traffic Curb

1. Construct in accordance with the referenced City of Seattle Standard Plan or as indicated and in accordance with COS Standard Specifications Section 8-04.3.

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**
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. Standard Specifications for Road, Bridge, and Municipal Construction.
      c. Traffic Control Manual for In-Street Work.
   2. Washington State Department of Transportation (WSDOT)
      a. Standard Specifications for Road, Bridge, and Municipal Construction.
   3. Federal Highway Administration (FHWA)
      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).
D. Traffic Control Plan: Plan will be part of and in accordance with Section 01 55 26, Traffic Control.

PART 2 - PRODUCTS

2.01 MATERIALS
A. 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.
1. All temporary and permanent pavement markings along Montlake Blvd., NE Pacific St., NE Pacific Pl., and within the UW parking lot will use COS standards and specifications.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. 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.

B. Removal of pavement markings shall be performed by method(s) approved by the Resident Engineer.

C. 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), or other method to be approved by the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
   A. This Section includes specifications for furnishing and installing security fencing, including gates, posts, fittings, hardware, anchors, and concrete footings, as indicated.

1.02 REFERENCES
   A. This Section incorporates by reference the latest revisions of the following documents:
      1. Washington State Department of Transportation (WSDOT):
         a. Standard Specifications for Road, Bridge, and Municipal Construction
         a. ASTM A121 Standard Specification for Metallic-Coated Carbon Steel Barbed Wire
         b. ASTM A585 Standard Specification for Aluminum-Coated Steel Barbed Wire
         c. ASTM F567 Standard Practice for Installation of Chain Link Fence
      3. American Association of State Highway and Transportation Officials (AASHTO):
         a. AASHTO M181 Standard Specification for Chain-Link Fence
         b. AASHTO T22 Standard Method of Test for Compressive Cylindrical Concrete Specimens
         c. AASHTO T152 Air Content of Freshly Mixed Concrete By the Pressure Method

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
   B. Product Data: Submit manufacturer's product data and specifications of the specified fencing and gates.
   C. Shop Drawings: Submit detailed shop drawings of the fences and gates layout, including installation details of the fencing, posts, gates, hardware, and accessories for review.
PART 2 - PRODUCTS

2.01 MATERIALS

A. General: Supply all fencing materials including fabric covering, framework, barbed wire and supporting arms, concrete footings, hardware, and all appurtenances and accessories as required for a complete installation. Construct fencing to heights indicated.

B. Chain Link Fencing Fabric: 9 gage, zinc-coated steel wire, conforming to AASHTO M181, Class C, woven into approximately 2-inch diamond mesh. Width and top and bottom finish of the fabric as specified in AASHTO M181.

C. Concrete Footing: Minimum compressive strength at 28-days of 3000 psi in accordance with AASHTO T22. Air entrain concrete with air content between 4.5-percent and 7.5-percent in accordance with AASHTO T152.

D. Post and Rails: Comply with WSDOT Standard Specification Section 9-16.1(1)A.

E. Tension Wire: Comply with AASHTO M181. Class 1 galvanizing.

F. Fittings and Hardware: Comply with WSDOT Standard Specification Section 9-16.1(1)D. Fittings for any particular fence shall be those that have been furnished by the manufacturer of the fence.

G. Chain Link Gates: Supply gate frames which are constructed of no less than 1-1/2 inch inside diameter hot-dip galvanized pipe with nominal weight of 2.72 pounds per linear foot.
   1. Fasten the corners of the gate frame together and reinforce with a malleable iron or pressed steel fitting designed for the purpose, or weld.
   2. Conform welding to the requirements of COS Specification Section 6-03.3(25). Grind welds smooth and paint with a high zinc dust content paint meeting the requirements of MIL-P-21035. Apply paint in one or more coats to provide a dry film thickness of 3.5 mils minimum.
   3. Cross Trussing: 3/8 inch galvanized steel adjustable rods.
   4. Provide each gate complete with necessary hinges, latch, and drop bar locking device designed for the type of gate posts and gate used. Provide a positive type latching device with provisions for padlocking.
   5. Gate frames constructed of steel sections, other than pipe, that are fabricated in such a manner as to form a gate of equal or better rigidity may be used with approval from the Resident Engineer.

H. Barbed Wire: Two wires twisted with 4-point barbs on 6-inch spacing.
   1. Zinc-Coated Steel Barbed wire: Comply with ASTM A121 Chain-Link Fence grade.
   2. Aluminum-Coated Steel Barbed wire: Comply with ASTM A585, Type 1.
   3. Line wire: 12.5 gauge and 14 gauge Barbs.

I. Barbed Wire Supporting Arms: Pressed steel or cast iron with clips, slots, or other means for attaching strands of barbed wire.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Construction Requirements

1. Stake locations of fence lines, terminal posts and underground utility locations. Clear and grade with adequate clearance on both sides of the fence line.

2. Install fencing and gates to meet the requirements of ASTM F567

3. Post Location: Spaced equidistant at intervals not exceeding 10 feet, unless noted otherwise.

4. Drop Bar Inserts: Install drop bar inserts in both the open and closed position of the gates to allow gate to be secured in either position.

5. Post Setting: Placed vertical, at the correct height and spacing and held in place during concrete setting.

6. Concrete fill: Placed around posts to dimensions indicated and vibrated or tamped for consolidation. Protect above ground portion of posts from concrete splatter.

7. Crown top of footings to shed water.

B. Remove and Reset Fence:

1. Portions of existing chain link fence that are removed and are to be reinstalled later, shall be protected from damage during removal and storage and reinstalled to the locations indicated.

2. Dispose of existing fence and gates which are damaged by construction operations and replace with new fence and gates of the same or equivalent type at no additional cost to Sound Transit.

END OF SECTION
1.01 SUMMARY

A. This Section includes specifications for furnishing and installing 2 new automatically controlled irrigation systems, herein noted as System ‘A’ and System ‘B’, and repair and expansion of 3 existing irrigation systems, herein noted as System ‘C’, System ‘D’ and System ‘E’. Coordinate all work with the Resident Engineer.

B. This Section also includes maintenance and operation of the irrigation system during the planting Warranty Period of 1 year duration to ensure the health and resumption of growth of planted materials. Refer to Section 32 90 00, Planting.

C. New irrigation consists of a completely automatic, electrically controlled irrigation system. The system is designed to provide complete coverage with minimum maintenance and prevent overspray onto walks, pavements, and structures.

D. Revised irrigation systems shall provide complete coverage of existing planting areas with minimum disturbance to existing planting to remain. Integrate new irrigation into the existing irrigation system. Ensure that irrigation outside work area remains operational.

E. Avoid conflicts with plant materials, lighting fixtures, sign posts, architectural features, above and below ground utilities, and drainage systems. Irrigation piping layout is schematic. Piping shall be located inside the planting areas and in sleeves under pavements between planting areas.

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 03 11 00, Concrete Forming.
2. Section 08 71 00, Door Hardware.
3. Section 31 20 00, Earth Moving.
4. Section 32 90 00, Planting.
5. Section 32 92 00, Turf and Grasses.

1.02 REFERENCES

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

1. American Society of Mechanical Engineers (ASME):
   a. ASME B16.3 Malleable Iron Threaded Fittings

a. ASTM A53/A53M Pipe, Steel, Black and Hot-Dip Zinc-Coated, Welded and Seamless
b. ASTM B3 Soft or Annealed Copper Wire
c. ASTM B33  Tinned Soft or Annealed Copper Wire for Electrical Purposes
d. ASTM D1785 Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
e. ASTM D2464 Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
f. ASTM D2467 Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
g. ASTM D3035 Polyethylene Pipe (PE), Class 160

3. American Water Works Association (AWWA):
   a. ANSI/AWWA C500 Metal Seated Gate Valves for Water Supply Service

4. National Electrical Manufacturers Association (NEMA):
   a. NEMA WC5 Thermoplastic Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.

B. City of Seattle (COS) Standard Specifications for Road, Bridge and Municipal Construction.

1.03 SUBMITTALS

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

B. Product Data: Include manufacturer’s product literature for all products to be installed in this system. Include material showing manufacturer’s name, catalog numbers, catalog cuts, technical data, installation, operation, and maintenance instructions for each product.

C. Point of Connection Water Pressure Test: Test water pressure at point of connection. Verify pressure is adequate for proper coverage from the specified irrigation heads. Submit written results of test to the Resident Engineer.

D. Existing Irrigation System Tests: Submit written results of existing irrigation systems tests to the Resident Engineer.

E. As-Built Drawings:

1. Record accurately with red ink on 1 set of prints all changes in the work constituting departures from the Contract Drawings, including changes in pressure and non-pressure line locations.

2. Record the changes and dimensions in a legible manner to the satisfaction of the Resident Engineer. Before final inspection of work, submit record drawings to the Resident Engineer for review.

3. Dimension from 2 permanent points of reference (buildings, monuments, sidewalks, curbs, and pavements). Record data shown on record drawings day-to-day as the Work is being installed.

4. Show locations, depths, size, and information as applicable, of the following items:
a. Points of connection and available static water pressure at each location.
b. Routing of sprinkler pressure lines and non-pressure lines (dimension maximum 100 feet along routing).
c. Spray sprinkler heads.
d. Gate valves.
e. Remote control valves.
f. Quick coupling valves.
g. Routing of control wires.
h. Locations of cut and capped existing sprinkler pressure lines and non-pressure lines.
i. Locations of cut existing control wires.
j. Related irrigation equipment as may be directed to accurately represent other authorized changes to the irrigation systems.

5. Maintain As-Built Drawings on Site.

F. Operation and maintenance manuals in accordance with Section 01 78 23, Operation and Maintenance Data.

1.04 SEQUENCING AND SCHEDULING

A. Coordinate installation of irrigation as shown on the Contract Drawings with all other Work of this Contract.

B. Coordinate layout and installation of irrigation sleeves, conduits, and piping under paved areas and other features prior to their construction.

C. Coordinate installation of irrigation system with preparation of planting areas. Refer to Sections 32 90 00, Planting, and 32 92 00, Turf and Grasses, for requirements. Install the irrigation system after planting beds have been prepared.

D. Install and test the irrigation system before installation of plant material except as noted in Article 1.04E, herein. Coordinate layout and installation of irrigation system with location and installation of plant material to ensure that there will be complete and full irrigation coverage of planting areas as indicated.

E. Stake tree locations in the field prior to installation of irrigation pipe and sprinklers. Refer to the plant list on the Contract Drawings for plant setbacks and spacing requirements. Trees and shrubs larger than 5 gallons container size shall be located and planted prior to installing the irrigation system.

F. Complete and test the repaired and replaced irrigation elements with the existing irrigation system prior to standard irrigation start-up on May 1. Cap existing pipe in a timely manner as specified herein. Coordinate with Resident Engineer.

1.05 TURNOVER ITEMS

A. Controller Charts:

1. Record Drawings require approval by Sound Transit before charts are prepared.
2. Provide 1 irrigation zone location chart, sized to fit inside controller door for each automatic controller. Show complete area covered by controller.

3. The chart is a reduced size copy of the As-Built Drawings. In the event that the controller sequence is not legible when the print is reduced, enlarge to a readable size.

4. Mark the chart with a different color to show the area of coverage for each zone.

5. Record on the reverse side of the controller chart a list of sprinkler zones complete with a description of the zone location, zone irrigation type, and zone planting type.

6. When completed and approved, seal chart between 2 pieces of 20 millimeter thick plastic, minimum. Install chart in controller enclosure using Velcro fasteners.

7. Complete irrigation zone location charts 10 Days prior to final inspection.

B. Operation and Maintenance Manuals: Within 10 Days prior to acceptance of construction, prepare and deliver to the Resident Engineer the required descriptive materials, properly prepared in 2 individually bound copies of the operation and maintenance manual. Describe the material installed in sufficient detail to permit operating personnel to understand, operate, and maintain equipment. Include spare parts lists and related manufacturer’s information for each equipment item installed. Include the following information in the manual:

1. Index sheet listing Contractor’s address and telephone number, including names and addresses of local manufacturer’s representatives.

2. Complete operating and maintenance instructions on major equipment.

3. Manuals: As specified in Section 01 78 23, Operations and Maintenance Data.

C. Special Tools and Spare Parts:

1. Supply the following items as part of the Contract:
   a. 4 percent additional sprinklers and nozzles of each type and spray pattern shown on the Contract Drawings.
   b. 2 wrenches for disassembly and adjustment of each type of sprinkler head installed.
   c. 2 keys for each automatic controller and controller enclosures.
   d. 1 coupler with 3/4 inch bronze hose bib, bent nose type with hand wheel, and 1 coupler key for each 5 quick couplers installed.
   e. 1 valve box cover key per 10 valve boxes.
   f. Backflow device valve handles.

2. Deliver tools and spare parts to the Resident Engineer at the conclusion of Contract final inspection.

D. Provide the following additional documentation at close of Contract:

1. As-Built Drawings.
PART 2 - PRODUCTS

2.01 MATERIALS
A. All materials and equipment to be new and the best grade of its kind. All items of equipment or material to be as indicated or specified by patent or proprietary name or names of manufacturer, or approved equal.

2.02 PIPE AND FITTINGS
A. General pipe material for buried irrigation systems: PVC except at risers and where indicated otherwise.

2.03 PIPING
A. PVC Pipe:
3. Schedule 80 female adapters for transition between PE and PVC Pipe.
B. PVC Threaded Nipples: 6 inches long, 1/2 inch diameter, Schedule 80, ASTM D1785.

2.04 PIPE FITTINGS
A. PVC Pipe Fittings:
B. PE Pipe fittings: Fused polyethylene or brass internal barb fittings with two stainless steel hose clamps at each location.

2.05 PVC PIPE JOINT COMPOUND AND PRIMER
A. Joint compound: Medium set, medium body joint compound, ASTM D 2564.
B. Primer: Tinted, compatible with joint compound, as recommended by manufacturer of PVC pipe.

2.06 IRRIGATION SPRINKLER HEADS
A. Pop-up Bodies: Use sprinkler pop-up bodies constructed of ultraviolet-resistant plastic construction, an integral check valve that holds up to 8 feet of head (3.50 psi), heavy duty retract spring, and pressure regulation capability in either the pop-up stem or under the nozzle. Use pop-up bodies with 12 inch risers for shrub beds, 6 inch risers around parking stalls, and 4 inch risers for lawn areas, unless otherwise noted on Contract Drawings. Sprinkler heads of the same type shall be by the same manufacturer. Use Rain Bird 1800 series with SAM-PRS, or accepted equal.
B. Use sprinkler nozzles constructed of high strength, ultraviolet-resistant and impact-resistant plastic with anti-clogging valve adjustment screw for flow and radius adjustment. Use nozzles that have matched precipitation rates for individual irrigation zones. Adjustable arc nozzle where specified on Contract Drawings.

1. Rotator nozzles: Walla Walla Sprinkler Company MP Rotator Series or accepted equal.
2. Spray nozzles: Rain Bird MPR series, or accepted equal.
3. Bubbler nozzles: Rain Bird, or accepted equal.

C. Use swing joints consisting of 1 Hunter SJ-512 with additional top and bottom 1/2 inch Marlex street ells on spray sprinklers, or accepted equal.

2.07 ELECTRIC REMOTE CONTROL VALVES

A. Electric remote control valves shall be compatible with the controller, provided with a straight or angle pattern, and manufactured for the purpose. Sizes as indicated on the Contract Drawings. Control valves shall meet the following requirements:

1. Normally closed, solenoid actuated globe pattern diaphragm type with valve pressure rating not less than 200 psi. Rain Bird PEB-PRS-D Series electric remote control valve, or accepted equal.
2. Valve body and bonnet: Glass-filled nylon, with nylon reinforced rubber diaphragm. Encapsulate solenoid coil in molded epoxy. Provide for internal parts to be removable from top of valve without disturbing valve installation.
3. Actuated by a low power, 2.0 watt, 24-V ac, 60 Hertz solenoid actuator.
4. Flow control stem and cross handle for regulating and shutting off water flow and bleed screw for manual operation without electrically energizing solenoid coil.

2.08 MASTER CONTROL VALVES

A. Master control valve shall be heavy duty, of brass or bronze construction, capable of operation from controller, installed underground with unions, equipped with standard cross handle operating wheel, 150 psi test rating.

1. System ‘A’: Normally closed, solenoid actuated globe pattern diaphragm type with valve pressure rating not less than 200 psi. Rain Bird GB-PRS-D Series remote control valve, or accepted equal. Size as shown on the Contract Drawings.
2. Systems ‘B’ and ‘D’: Normally open, solenoid actuated globe pattern diaphragm type with valve pressure rating not less than 200 psi. Superior 3300 Series remote control valve. Size as shown on the Contract Drawings.

2.09 UNIONS

A. Unions shall be threaded PVC Schedule 80 and provided on both sides of strainers, backflow prevention assembly, and pressure reducing valves. Only use compression couplings or unions downstream from electric remote control valves unless necessary for installation.

2.10 IRRIGATION VALVE BOXES AND VALVE KEYS

A. Electric remote control valves: Carson 1324, or accepted equal. Black color with non-hinged T-cover. Extensions as required, bolt installed. One valve per box.
B. For capped existing mainline and valve wires: Carson Standard 1419, or accepted equal. Size: 17 inches by 12 inches by 12-1/4 inches deep. Black color with non-hinged cover. Extensions as required, bolt installed.

C. Gate valves: Carson 910 round, or accepted equal. Black color, set on PVC riser.

D. Backflow assemblies: concrete vault with hinged locking metal lid, Utility Vault Model 25-TA, or accepted equal.


F. Quick coupler valves: as shown on Contract Drawings.

G. Provide 1 set of keys required for valves, valve box covers and protective sleeve caps. Provide 2 sets of keys required for automatic controller box cover.

2.11 AUTOMATIC IRRIGATION CONTROLLER

A. System ‘A’:

1. Provide controller for complete automatic operation of irrigation system; commercial grade, in weatherproof, lockable box or cabinet, UL listed and with adequate number of zones to operate system. Provide zones with independent time controls with 1 minute incremental settings up to 60 minutes maximum per zone. Provide controllers to allow easily made changes on zone timing and programs start time without tools or disassembling. Zones may be omitted with time setting of zero minutes. Provide rapid advance between zones and override on each zone for manual operation. Provide for schedules up to 1 week and permit multi-cycle operation as often as every hour. Equip controller with manual start switch for activation of semiautomatic watering cycle.

2. Capable of operating 24-V ac electric remote control valves.

3. Provide a UL listed 24-V ac transformer with controller. Color-code zone wiring with irrigation zone indicator key visibly imprinted. Include pump start or master valve control with controller and circuit overload protection to prevent damage due to voltage surges.

4. Controller housing: Heavy-gauge steel coated with rust inhibitor; finish with industrial gray enamel, weatherproof cabinet, NEMA Type 4. Gasket controller door and provide covered, heavy-duty lock for protection against theft and vandalism. Mount controller components on face panel for easy removal. Print operating instructions on face of controller for easy access when programming.

5. Lock Cylinder and Master keying: As specified in Section 08 71 00, Door Hardware.


B. System ‘B’ and ‘D’:


2.12 IRRIGATION CONTROL WIRE

A. Provide thermoplastic insulated, solid copper conductor conforming to ASTM B3, suitable for continuous operation at 24-V ac.

B. Direct burial control wires to electric remote control valves: NEC Type UF, G.E. Co. No. SI-58-51, or accepted equal. Size wire to each remote control valve to not exceed 5 percent voltage drop from impressed voltage, not less than No. 14 AWG.


D. Wire splices: 3M-DBR, or approved equal.


F. Cable for flow sensor: Direct bury, shielded, two 18 or 20 AWG copper wires with drain wire. Rain Master EV-CAB-SEN, Houston Wire D1501802, or approved equal.

2.13 WIRE SLEEVE

A. Conduit below paving: Schedule 40 PVC sized in accordance with irrigation details, or as required to accommodate the number of control wires at each sleeve.

2.14 BACKFLOW PREVENTER

A. Double check valve assembly with the following:
   1. Internally spring-loaded isolation valves, 2 ball valves, and 4 field test cocks.
   2. All check valve internal parts to be easily accessible from top of device without removing check valve body from line.
   3. Assembly to be rated 175 psi working pressure.
   4. Install washed pea gravel under assembly to provide adequate drainage.
   5. Backflow preventer size to be same as pipe or larger.
   6. Febco, Watts, or accepted equal.

2.15 FLOW SENSOR

A. System ‘B’: Data Industrial IR-250B-1.25.

B. System ‘D’: Data Industrial IR-250B-1.25.

2.16 GATE VALVES

A. ASTM B-62 Bronze body, bonnet, handwheel and solid wedge. Non-rising stem.

B. Valve: Nibco T-113-BHW, or accepted equal.
2.17 PRESSURE REDUCING VALVE
A. Brass body, pressure rating 300 psi. Pressure range 25 to 75 psi adjustable. Factory pressure set at 50 psi. Integral stainless steel strainer. Watts 25AUB-DU-Z3, or accepted equal.

2.18 WATER METER
A. System ‘B’ irrigation deduct water meter:
   1. Coordinate University of Washington irrigation meter requirements with Resident Engineer.
   2. Meter shall be compatible with University of Washington DDC system. DDC vendor shall verify compatibility with DDC system. The meter shall be sized for the anticipated flow rates.
   3. Meter type: disc, compound or turbine. Capable of measuring cumulative water consumption measured in cubic feet and be equipped with a local display.
   4. The meter shall have the ability to be trended and logged in 15-minute increments through the DDC system.

2.19 QUICK COUPLER VALVES
A. Quick coupler valves shall be 2 piece body type of heavy duty brass or of heavy duty bronze and watertight both before and after the coupler is inserted. The valve mechanism is to be so designed that the valve seat is closed before the coupler is removed. Each valve shall have the manufacturer’s identification cast or stamped on the valve.
B. Quick coupler valve:
   1. Type 1: Rain Bird 44LRC with locking rubber cap, or accepted equal.
   2. Type 2: Buckner QB44RC-10 with rubber cap, or accepted equal. Install with DL-010 quick lock, or accepted equal.
C. Swing joint: Dura 1-A4-1-11-18, or accepted equal.
D. Concrete protector ring for System B, C, D, and E quick couplers:
   1. Furnished by University of Washington. Coordinate with Resident Engineer.

2.20 BALL VALVES
A. KBI low torque, slip by slip, sized same as pipe size.

2.21 WYE STRAINER
A. Cast bronze body, wye-pattern, threaded connections, 200 mesh stainless steel strainer.
B. Manufacturers: Watts, Wilkins, Mueller, or accepted equal.
PART 3 - EXECUTION

3.01 GENERAL

A. Test each existing irrigation system that will be revised as shown on the Contract Drawings. Coordinate access and operation of each existing irrigation system with the Resident Engineer. Note operational status of each section of each existing system to be revised. Measure static pressure at each point of connection and verify that pressure is adequate for proper sprinkler coverage as shown on the Contract Drawings. Report operational status and pressure measurements to the Resident Engineer for each existing irrigation system.

B. Unless otherwise indicated, irrigation system shown on plans is schematic. Coordinate repair and replacement of existing irrigation elements with other work. Coordinate cutting and capping of existing piping and wire and protect existing piping and wiring from damage during work performed under this contract. With approval of the Resident Engineer, make adjustments where necessary to conform to the actual field conditions. Irrigation system to be operational with uniform and adequate coverage of areas to be irrigated prior to planting.

C. Service connections: As indicated or designated by utility company; installed by others at no cost to Contractor. Notify the Resident Engineer at least 3 weeks before electrical and water services are required. Furnish labor and materials to connect to the service connection.

D. Water Supply: Connect to or install water supply at locations indicated. Make minor changes caused by actual site conditions. Arrange for and pay costs associated with water meter installation.

E. Electrical Service: Make 110-V ac connection to irrigation controllers.

F. Code Requirements: Before Work of this Section, carefully inspect installed Work of other trades and verify that the Work is complete to the point where irrigation system installation may commence properly. Verify irrigation system may be installed in accordance with pertinent codes and regulations, original design, referenced standards and manufacturer's recommendations.

1. Immediately notify the Resident Engineer of conflicts between equipment or methods indicated or specified with local codes, prior to start of installation. If Contractor fails to give notification, assume responsibility for cost of revisions necessary to comply with code.

G. Grades: Before starting Work, carefully check grades to determine Work may proceed safely; keep within specified material depths with respect to finish grade.

H. Conduct all irrigation work within tree protection areas as specified in Section 01 56 39, Temporary Tree and Plant Protection.

I. Coordination with work of other trades: Make necessary measurements in field to ensure precise fit of items in accordance with original design. Coordinate installation of irrigation materials with other work. Coordinate piping locations and tree and shrub locations to avoid conflicts. Coordinate with Resident Engineer for locates, protection, restoration work, inspection, and testing.

3.02 INSTALLATION

A. Excavating and Backfilling:

1. Perform excavation and backfilling as specified in Section 31 20 00, Earth Moving. Restore existing surfaces to original condition.
2. When encountering irrigation piping or wiring, do not rip piping or wiring out of the ground with backhoe or other earth moving equipment. Chase piping and wiring to excavation limits and make clean cuts. If pipe is not immediately capped, cover exposed ends with duct tape.

3. Photo document exposed piping. Include wide angle shots referencing identifiable elements which will remain after completion of work. Provide a minimum of 3 digital photos of each location to Resident Engineer.

4. Trenching of new mainline and lateral runs shall be straight and without abrupt grade changes.

5. Trenches shall be free from rock, debris or sharp articles, with a minimum of 12 inches of cover over lateral lines, 18 inches of cover over mainline. Trench width must allow a minimum of 2 inches between parallel pipelines. No stacking of pipe permitted. Trench bottoms with uniform slope 1/2 percent standard minimum grade.

6. Backfill any excess excavation with suitable materials in conformance with Sections 31 20 00, Earth Moving, and 32 90 00, Planting, which is free of rocks, organic material, or other materials that may damage pipe. Thoroughly compact to give full support to pipe. Backfill when pipe is not in an expanded condition due to heat or pressure. Place backfill material in 6 inch lifts and compact each lift. Backfill to ensure no future settlement of the trench. Thoroughly backfill around sprinkler heads and be especially attentive to the restriction of movement of heads by external force. Repair all trench settlement during the warranty of this contract. Backfill trenches uniform with the surrounding grade.

7. Backfill in irrigation sleeve trenches shall be mechanically compacted in 2 lifts to a dry density equal to 95 percent of adjacent undisturbed soil. Backfill will conform to adjacent grades without dips, sunken areas, humps, or other surface irregularities.

8. If settlement occurs and subsequent adjustments in pipe, valves, sprinkler heads, lawn or planting, or other construction are necessary, the Contractor shall make all required adjustments.

9. Compaction: Use hand-operated, plate-type, vibratory, or other suitable hand tampers in areas not accessible to larger rollers or compactors. Compact initial backfill material surrounding pipes and conduits to 90 percent maximum density. For pipes, conduits, and sleeves under roads or slabs, compact backfill as specified in Section 31 20 00, Earth Moving.

B. PVC Pipe Assembly:

1. Handle plastic materials carefully, store under cover and prevent damage to pipe. Provide support beds for full lengths of pipe when transporting and storing pipe. Do not install damaged or dented pipe.

2. Cut PVC pipe square and remove burrs. Clean pipe and fittings using primer and cleaner recommended by PVC pipe manufacturer. Use tinted primer to aid in visual inspection.

3. Apply light coating of joint compound to both male and female ends while primer is still moist, rotate 1 quarter turn when making connection, and hold until secure. Cure joints as recommended by manufacturer and keep pipe and fitting out of service during curing period. Construct watertight joints equal to or greater in strength than pipe. Do not tap pipe and fittings.
4. Wipe off excess solvent cement with a clean rag. Let welded joints cure at least 15 minutes before moving them and at least 24 hours before water is permitted into pipe.

5. Do not allow debris to enter existing pipe to remain operable. If capping cannot be completed immediately after cutting, cover exposed end of pipe with duct tape. If piping is contaminated, flush affected piping as needed to clear debris.

6. Install pipe fittings for sprinklers, electric remote control valves, and quick coupler valve outlets horizontally and facing the exterior of the planting area.

7. Install inline check valve within laterals of sprinkler zones where vertical elevation change exceeds the range of sprinkler integrated check valves.

8. Do not install new mainline or lateral, nor modify existing mainline or lateral terminations without a means of venting air. For mainlines, install quick coupler valves at terminations or chase piping back to trunk line with means of air release and cap. For laterals, install a sprinkler or chase piping back to nearest sprinkler and cap. Install a Schedule 80 molded fitting slip cap on all existing mainlines and lateral lines that have been cut.

9. Do not vertically stack piping in trenches. Install piping side by side with 2 inch separation between parallel pipes.

10. PVC Pipe Sleeves: provide pipe sleeves double the diameter of the interior irrigation pipe. Cover sleeves with a minimum of 18 inches.

C. Backflow Preventer:

1. Install unit as indicated on Contract Drawings. Verify exact location with the Resident Engineer before installation.

2. The backflow prevention assemblies shall be inspected and tested before use in accordance with the applicable portions of the Washington Administrative Code and other applicable regulations as set forth by the Washington State Department of Health and the City of Seattle. No water shall flow through the assembly until testing and inspection is approved by the Resident Engineer.

3. These inspections and tests shall be completed and the results recorded by a licensed Backflow Assembly Tester (BAT) Operator or by a Contracting Agency Certified Water Works Operator with a CCS-1 or CCS-2 Classification. Document that the devices are in good operating condition prior to flushing and testing of any downstream water lines.

4. Installations shall be according to procedures outlined in the current edition of “Accepted Procedure and Practice in Cross-Connection Control Manual,” published by the Pacific Northwest Section, American Water Works Association.

D. Electric Remote Control Valves:

1. Before installation, the supply line must be thoroughly flushed. Use valve box extensions by same manufacturer to ensure that box extends completely below the bottom of the valve. Install locking cover bolts.

2. Valve boxes to be installed perpendicular to walks and curbs. Placed a minimum of 3 feet from curbs, walks, and pathways.
3. Valve boxes to be set on a masonry brick at each corner. Provide a 1-inch clearance above pipe.

4. Valve boxes to be sealed with filter fabric wrapped around the entire lower portion of the valve box and secured with duct tape to outside of valve box.

E. Sprinkler Heads:
   1. Install sprinkler heads as indicated on Contract Drawings.
   2. Thoroughly flush lateral piping and swing joints prior to installation of sprinklers.
   3. Install sprinkler heads flush with finish grade adjacent to walks and curbs as detailed. Lower heads to grade before completion of maintenance period.
   4. Upon completion of installation, adjust heads to properly distribute water flow. Adjust adjustable sprinkler heads by fully opening sprinkler head farthest from control valve. Open manual adjustment of control valve slightly to obtain a 24 inch high spray at sprinkler head mentioned above. After this condition has been met, adjust other sprinklers in that section for equal height sprays, regulating control valve as required to maintain condition. Adjust control valve to obtain catalog rate pressure for sprinkler installed. Rotate individual heads to keep sprays within areas of shrubs and groundcover.

F. Swing Joints: Connect sprinkler head assemblies to laterals using a swing joint assembly as shown on Contract Drawings.

G. Control Wire:
   1. Cut existing valve wires allowing for a minimum of 4 feet of extra length to be coiled into valve box.
   2. Verify zone designation on existing controller for each valve wire cut and clearly mark zone number on wire with a durable plastic tag marked with a permanent marker.
   3. Wiring to comply with National Electrical Code, latest edition, and have a common neutral, white, and separate control conductor for each valve.
   4. Splices will be permitted only at junction boxes or valve boxes. A minimum of 2 feet of excess conductor is to be left at all splices, terminal, and control valves to facilitate inspection and future splicing. Encapsulate all splices with wire connectors.
   5. Control wires to be taped together at 5-foot intervals with electrical tape, then this bundle is to be taped to the bottom of new lengths of main line at 10-foot intervals with at least 1 full wrap of duct tape. Tie a loose 24 inch loop in all wiring runs at changes of direction greater than 30 degrees. Untie all loops after all connections have been made.
   6. Provide dedicated trace wiring for the mainline and each zone of Systems B, C, D, & E. Install trace wires on top of pipes.
   7. When backfilling around valve box, make sure that spare wires are exposed and accessible in the existing valve box with new mainline connection. Loop a 24 inch coil of spare wire inside valve box.
   8. Lay lines connecting controller and remote control valves in trenches with a minimum cover of 18 inches of soil. Bind wires in bundles with friction tape every 10 feet.
9. Encase wire under paving in Schedule 40 PVC pipe. Provide continuous wire runs without splices between control valves; splice only at control valves or junction box locations.

10. Install 2 spare orange signal wires to run from the controller to the furthest ends of each main line termination.

H. Sleeves: Place pipe to be installed under roadways, walkways, bike paths and maintenance access areas in a galvanized steel or Schedule 80 PVC sleeve that has an inside diameter not less than 2 inches larger than outside diameter of pipe or combined outside diameter of pipes installed.

I. Controller Installation:

1. Coordinate electrical service to controller location. Install wall-mounted and pedestal-mounted controllers as shown on Contract Drawings.

2. Program irrigation system to operate after plants have been installed, without conflict with other work.

3.03 INSPECTION

A. Notify Resident Engineer to coordinate inspection of each initial irrigation assembly with University of Washington representative for Systems B, C, D & E. Irrigation assemblies include installations of points of connection, irrigation controller, remote control valves, initial PVC pipe solvent welding, sprinklers assemblies, and quick coupler valves assemblies.

B. At completion of installation, and before planting of shrubs or groundcover, inspect overall coverage of new system and existing system to remain for zones affected by this work. Demonstrate the working system to the Resident Engineer.

C. Do not cover installed work before the Resident Engineer has inspected installation. Uncover covered work at no additional cost to Sound Transit.

D. Completely check system within 5 days before final inspection. Properly align heads and adjust for coverage. Clear system of foreign materials. Properly adjust valves. Check sprinkler controller valve chart for accuracy.

E. At end of Warranty Period make a final inspection of system with the Resident Engineer.

3.04 TESTING

A. Test all irrigation lines which have been installed as new work and that have been affected by this work. Perform tests in presence of the Resident Engineer. Give at least 48 hours advance notice of tests.

B. Hydrostatic pressure testing of sprinkler lines:

1. Leave all system joints, connections, and other fittings exposed until after completion and acceptance of pressure test. All subsequent breaches of integrity of mainlines shall require re-testing.

2. Mainlines and supply lines: Test mainline for 1 hour at 150 psi. Test mainlines of existing systems which have been cut and capped at static pressure equivalent of current operating pressure. Mainline test will include installed electric remote control valves, isolation ball valves, quick coupler valves, gate valves, and point of connection assembly. Ensure means of air release at terminations and bleeding of
all trapped air. Test will fail if pressure loss is greater than 5 psi during the duration of the test.

3. Laterals: Test laterals at 100 psi for 30 minutes. Test laterals of existing systems which have been cut and capped at 80 psi. Lateral test will include all swing assemblies with temporary threaded caps on the downstream Marlex fitting. Wrap caps with 3 wraps of Teflon tape. Ensure means of air release at terminations and bleeding of all trapped air. Test will fail if pressure loss is greater than 5 psi during the duration of the test.

4. Center load pipe with small amount of backfill to prevent arching and movement under pressure. Leave joints exposed for inspection during pressure test. No water is permitted in pipe for pressure testing until a period of at least 24 hours has elapsed for solvent weld setting and curing.

5. Test each system as a unit or in sections. Successfully meet specified requirements for each section before acceptance.

6. Test by capping each outlet and filling pipeline with water. Maintain specified pressure for duration of test and determine leakage. Immediately correct leaks and subject system to same test. No pipe, fitting or joint showing leakage will be accepted. After piping has been tested to satisfaction of the Resident Engineer, backfill pipe trenches before adjustment and testing of sprinklers and valves.

7. Furnish necessary force pump and other test equipment. Attach test compressor with pressure gauge to head of mainline near existing Double Check Valve Assembly.

8. Contractor is only responsible for leakage of the existing irrigation piping within 20 feet of excavations, unless it has been determined by the Resident Engineer that damage has occurred beyond this point by this Work.

9. Do not cover installed Work before the Resident Engineer has inspected installation. Uncover Work as directed by the Resident Engineer for testing.

C. Automatic Sprinkler Controller and Wiring:

1. Test the electronic operation of the irrigation system after installation. Test will include operation of remote control valves and master valve via the controller. For Systems B, C, D, and E, the test will also include operation of the flow sensor via the controller, and communication loop testing via the University of Washington irrigation central control system.

2. Test controller schedule operation for 7 days immediately prior to the end of Warranty Period. Operate system automatically in manner indicated.

3.05 CLEAN UP

A. Upon completion of Work, clean up excess materials, equipment, and rubbish resulting from Work. Leave premises in a clean, neat, and orderly condition.

3.06 TRAINING

A. The Contractor shall provide a course on the use, adjustment, and maintenance of the automatic controller and irrigation sprinklers 30 Days prior to completion of the Warranty Period. The instructions shall be given in 1 course of three 8-hour days at a Sound Transit Office or on Site as arranged for by Sound Transit.
B. Approximately ten maintenance persons will attend the course. The Contractor shall schedule the course through the Resident Engineer at a time convenient to Sound Transit. The Contractor shall notify the Resident Engineer of the proposed course dates at least 6 weeks before those scheduled dates.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for: soil preparation of all planting areas to include discing, installation, amending, incorporation, and mixing to prepare soils; fine grading; furnishing, installation, and maintenance of planting; staking and guyng of trees; mulching of planting areas; fertilization; cleanup; and warranty of all trees, shrubs, and groundcovers.

B. This Section also includes a Warranty Period of 1 year duration to ensure the health and resumption of growth of planted materials.

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 20 00, Earth Moving.
2. Section 32 84 00, Planting Irrigation.
3. Section 32 92 00, Turf and Grasses.

1.02 REFERENCES

A. This Section incorporates by reference the latest revision sof the following documents.

1. American Association of Nurserymen (AAN):
   a. American Standard for Nursery Stock, ANSI Z60.1 (ASNS)

2. American Joint Committee on Horticultural Nomenclature:
   a. Standardized Plant Names (SPN)

1.03 DEFINITIONS

A. FSC (Forest Stewardship Council) accredited certifying agencies including:

1. SmartWood Program, administered by Rainforest Alliance (802-434-5491).


3. A complete list of internationally accredited FSC agencies (www.fscoax.org).

B. Soils:

1. Topsoil: Imported soil used as a component of prepared planting soil for non-rain garden planting areas, conforming to the product description in this Section.
2. Prepared Planting Soil: Mixture of native soil and topsoil as described in this Section.

3. Native Soil: Existing, undisturbed soil.

4. Planting Backfill: Mixture of native soil and topsoil for tree and shrub planting pits that exceed the prepared planting soil depth for the planting areas.

5. Gravel Sedum Mulch: Imported soil for tree pit areas illustrated in Contract Documents, conforming to the product description in this Section.

1.04 SUBMITTALS

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

B. Source of Supply Plan.

C. Delivery, Storage, and Handling Plan.

D. Schedule and Work Plan.

E. Temporary irrigation plan.

F. Product Data: Submit product literature or tear sheets giving name of product, manufacturer's name, and compliance with Contract Specifications.
   1. Commercial fertilizer.
   2. Anti-desiccant.

G. Samples:
   1. Organic mulch: One-pound bag.
   2. Guying material: One-12 inch length.
   5. Gravel Sedum Mulch: One-pound bag.

H. Certifications: Submit with certificate names of materials and manufacturer.
   1. Commercial Fertilizers: Include guaranteed analyses.
   2. Plant Material: Furnish certificates of inspection as may be required by Federal, State or other authorities that plant material is free of disease or hazardous insects.
   3. Sedum Cuttings: Furnish certificates of inspection as may be required by Federal, State or other authorities that plant material is free of disease or hazardous insects.
   4. Ground Dolomitic Limestone: Include guaranteed analysis and weight of packaged material.
5. Organic Amendment: Include acid reaction, content of woody material, water absorbing capacity and moisture content by weight.

6. Wood Stakes: FSC 1.2 Certification.

I. Test Reports:

1. Employ an approved agricultural testing laboratory to perform soil testing. The soil testing laboratory must be accepted by the Resident Engineer in advance. The testing lab must be a member of the Soil Science Society of America's, North American Proficiency Testing Program (NAPT).

2. Submittal for prepared planting soil:
   a. Test prepared planting soil in three locations, including one sample tree planting pit, as selected by the Resident Engineer. Follow soil testing lab's instructions for soil sample collection.
   b. The test shall provide the following: pH and buffer pH; percent organic content by oven dried weight; nutrient levels by parts per million including nitrogen, phosphorus, potassium, magnesium, manganese, iron, zinc and calcium; soluble salt by electrical conductivity of a 1:2 soil water sample measured in Milliohm per cm; and Cation Exchange Capacity (CEC).
   c. Nutrient test shall include the testing laboratory recommendations for supplemental additions to the prepared planting soil. Chemical analysis shall include recommendations from the soils laboratory as to ranges of each chemical element appropriate for the types of plants to be grown in the prepared planting soil.
   d. If soil does not meet criteria established by the agricultural chemist for growth of healthy plantings, submit a program of additional amendments based on recommendations of the agricultural chemist.
   e. Schedule testing such that it does not interfere with construction schedule. Test report submittals for all areas must be accepted prior to any planting.

J. Photographs of plants: Submit representative photograph of each plant species being held 60 days prior to planting, or 30 days prior to final digging deadline for the planting season (whichever is sooner).

1.05 QUALITY ASSURANCE

A. Landscape contractor: Licensed in the State of Washington with at least 5 years experience on projects of similar scope and experienced in landscape work of the highest professional quality. Firm shall have equipment and personnel adequate to perform the Work specified.

B. Underground Utilities: Protected. Repair any damage to original condition.

C. Protection: For all Work in progress. Protect adjoining property, and be responsible for protection from bodily injury due to construction operations.

D. Restoration of existing vegetation areas to remain: Restore areas damaged during construction as approved by Resident Engineer. Restore all lawn, planting, trees and irrigation in surrounding areas damaged during construction according to accepted horticultural practice and in accordance with this Section as well as Section 01 56 39,
Temporary Tree and Plant Protection, Section 32 84 00, Planting Irrigation, and Section 32 92 00, Turf and Grasses.

E. Permits, Codes and Regulations: assure all work is in accordance with all applicable codes, regulations, and all related documents including but not limited to:

2. Seattle Department of Transportation.

F. Quality of Work: equal to best accepted trade practices.

G. Settlement Test: Install 20 square feet of prepared planting soil and rain garden soil at specified depth and apply irrigation to induce settlement. Supplement specified depth with additional topsoil to achieve specified grade conditions.

1.06 REGULATORY REQUIREMENTS

A. Investigate the conditions of public thoroughfares and roads as to availability, clearances, loads, limits, restrictions, and other limitations affecting transportation to, ingress, and egress at the site. Ship landscape materials with certificates of inspection required by governing authorities. Conform to all governmental regulations regarding the transportation of materials.

1.07 SOURCE OF SUPPLY PLAN

A. Submit plan for the procurement of plant material within 60 Days of project notice to proceed. Include:

1. Plant List.
2. Documentation that plants are being contract grown or deposits have been provided to nurseries to ensure availability.
3. Name and contact information of growers.
4. Representative photographs of supplier’s stock.

B. Should the nursery stock at any time be lost or compromised due to weather or other natural occurrences, notify the Resident Engineer immediately of the need to locate new material.

1.08 DELIVERY, STORAGE, AND HANDLING PLAN

A. Indicate:

1. Proposed location for on-site plant holding.
2. Water source.
3. Protection measures during various seasonal conditions.

1.09 SCHEDULE AND WORK PLAN

A. Submit 1 week prior to landscape preconstruction meeting the proposed planting schedule.
B. Indicate:

1. Dates for each type of landscape work during normal seasons for such work in the area of the site.
2. Substantial Completion Date.

C. Once accepted, revise dates only as approved in writing, after documentation of reasons for delays.

1.10 TEMORARY IRRIGATION PLAN

A. Submit 1 week prior to landscape preconstruction meeting the proposed temporary watering plan for restoration areas indicated in Contract Documents. Plan shall include:

1. Proposed watering schedule and rates to establish restoration areas.
2. Proposed equipment and layout, if applicable.

1.11 DELIVERY, STORAGE AND HANDLING

A. Refer to Section 01 66 00, Product Storage and Handling Requirements.

B. Delivery:

1. Delivery fertilizer and plant treatment materials to the site in original unopened containers bearing manufacturer’s guaranteed chemical analysis, weight, manufacturer’s name, trademark, and conformance with state law.
2. Label trees, shrubs, and groundcovers. State correct plant name and size as indicated on the plant list on the Contract Drawings.
3. Prevent and windburns on trees during transportation. Provide adequate protection so that trunks are not scarred in transport and branches are not broken.
4. Notify the Resident Engineer in advance of delivery of plant materials and submit an itemized list of the plants in each delivery.
5. Sedum Cuttings: Take all necessary precautions to prevent rot or drying out during delivery and storage. Cuttings to be kept cool, using cold during transportation and storage if necessary for survival.

C. Plant Selection and Inspection:

1. Tagging Plant Material: Attach legible labels to each individual plant, or container containing one or more plants. Provide the necessary detailed information as to horticultural name, size, or other data required to identify as conforming to specifications on the label. When the label is attached to a container containing more than one plant, mark quantity as well as other required information on the label. Refer to Nursery Stock Standards regarding labeling of plant material. The Resident Engineer will reject plant material with illegible or missing tags.
2. Arrange a preconstruction meeting between the Resident Engineer, landscape architect, Contractor, and planting Subcontractor to review the proposed landscape schedule, source of plants, consideration of substitutions, review of specifications, and planting procedures.
3. Inspection of Plant Material: Allow the Resident Engineer opportunity to inspect plant material at nursery or offsite holding area prior to arrival on site. All plant materials will be inspected by Resident Engineer after arrival on site. Notify the Resident Engineer 4 working days prior to the proposed arrival of plant materials on site. Arrange for adequate manpower and equipment on site at the time of plant material inspection and installation to provide a complete staked layout and to unload, open, and handle plant material during inspection. Immediately remove plants not meeting the requirements herein specified or matching approved representative photographs from the project and replaced at no additional cost to Sound Transit.

4. Sedum Cuttings that are thin or dehydrated and which are considered by the Resident Engineer to be sub-standard shall be rejected.

5. Sedum Cuttings shall be planted within 12 hours of removal from refrigeration, or as approved by Resident Engineer.

D. General Temporary Storage:

1. If planting is delayed more than 24 hours after delivery, set balled and burlapped plants on the ground well protected with soil, wet peat, or other acceptable means of retaining moisture as accepted by the Resident Engineer. Protect balls and roots and container grown material from freezing, sun, drying winds, and mechanical damage.

2. Water as necessary until planted. Immediately install plant material delivered and accepted.

3. Plants stored under temporary conditions accepted by the Resident Engineer are the sole responsibility of the Contractor.

4. Do not heel in plants for more than 1 week. Provide temporary storage, in accordance with accepted Delivery, Storage, and Handling Plan.

5. Plants temporarily stored are subject to inspection and approval prior to planting. Immediately remove rejected plant material from the site.

6. Do not remove container-grown stock from containers until planting time.

7. Plants: Do not prune prior to delivery. Apply antidesiccant and provide protective covering during delivery.

E. Handling:

1. Exercise care in handling, loading, unloading and storing of plant materials. Plant materials damaged in any way shall be discarded and replaced with undamaged materials.

2. Protect packaged materials from deterioration during storage. Fertilizer and plant treatment materials shall not be stored with any other landscape material.

1.12 PROJECT CONDITIONS

A. Environmental Requirements: Do not plant when the ground is frozen, or the soil is otherwise in an unsatisfactory condition for planting. Do not plant during periods of excessive heat, drought, moisture and cold. Correlate planting with specified maintenance periods from date of Substantial Completion.
B. Environmental Requirements: Work soil only during suitable weather conditions. Do not disc, rototill, or work soil when ground is frozen, excessively wet, or in otherwise unsatisfactory condition.

C. Existing Conditions:

1. Carefully examine the site before submitting a Bid. Be informed as to the nature and location of the Work; general and local conditions including climate, adjacent properties and utilities; confirmation of the ground; the nature of subsurface conditions; and the character of equipment and facilities needed prior to and during execution of the Work.

2. Excavation: When conditions detrimental to plant growth are encountered, such as rubble fill, adverse drainage conditions, or obstructions, notify the Resident Engineer before planting.

3. Proceed with and complete landscape work as rapidly as portions of the site become available, working within seasonal limitations for each kind of landscape work required.

4. Utilities: Determine location of underground utilities and perform work to avoid possible damage. Hand excavate, as required. Maintain grade stakes set by others until concerned parties mutually agree upon removal.

5. Should the Contractor, in the course of work, find discrepancies between Contract Drawings and physical conditions or omissions or errors in Contract Drawings, or in layout as furnished by the Resident Engineer, inform the Resident Engineer immediately in writing for clarification. Work done after such discovery, unless authorized by the Resident Engineer, is at the Contractor's risk.

1.13 SEQUENCING AND SCHEDULING

A. Coordinate Work of this Section with other Work.

B. Planting Time: Install plants in the planting season beginning October 1 through April 30, unless otherwise approved by the Resident Engineer.

C. Coordinate earthwork and soil preparation. Do not expose soil stockpiles for longer than 15 days without temporary or permanent vegetative, or other, cover. Test any soil stockpiles exposed longer than 15 days in accordance with testing requirements.

D. Landscape work shall not begin until structures, utilities, paving, and other improvements which require access to, or through, planting areas have been installed and accepted by the Resident Engineer. Planting work shall not begin until the landscape irrigation system is installed in place, tested, and accepted by the Resident Engineer.

E. Sedum Sowing Time: Sowing sedums is restricted between March 1 to April 30 and September 1 to October 30. Confirm schedule with Resident Engineer.

1.14 SUBSTANTIAL COMPLETION

A. The Resident Engineer will make an inspection for Substantial Completion of the work of this Section. The Contractor will furnish a full and complete written program for maintenance of the planting during the Warranty Period for review by the Resident Engineer at the time of the request for acceptance.

B. Submit a written request for inspection at least 4 days prior to the day on which the inspection is requested.
C. All planting shall be alive, healthy, and installed as specified to be accepted.

D. Upon completion of planting, and prior to receipt of certificate of Substantial Completion, remove from site excess soil and debris and repair all damage resulting from planting operations.

E. The Contractor is to prepare a list of items to be completed or corrected for review by the Resident Engineer.

F. Upon completion of the inspection, the Resident Engineer will amend the list of items to be completed or corrected, and indicate the time period for their completion or correction.

G. The Warranty Period will not begin until all items have been completed or corrected.

1.15 WARRANTY PERIOD

A. General: The Contract shall provide adequate and proper care for plant materials and landscape areas within the Contract limits during the Warranty Period to ensure the health and resumption of growth of the plant materials. The Warranty Period begins after the date of the Substantial Completion and ends 1 year thereafter. Substantial Completion will be certified in writing by the Resident Engineer.

B. Make warranties in addition to and not in lieu of all other liabilities, which manufacturers or Contractor may have by law or by other provisions of the Contract Documents.

C. The Contractor is responsible for maintenance of all plant materials from construction through the end of the Warranty Period. It is the Contractor's responsibility to regularly inspect the plant materials to satisfy themselves that the areas are receiving proper care.

D. Warranty for plants:

1. Replace at no additional cost to Sound Transit for a period of one year after the establishment of the beginning date of Warranty Period, plants that have died or that are, in the opinion of the Resident Engineer, in unhealthy or unsightly condition, or that have lost their natural shape due to dead branches, excessive pruning, or excessive defoliation. Make replacement within 7 days of notification from the Resident Engineer. Remove dead plants within two days of notification and mark planting plan showing the exact location of replaced plants.

2. Replace unacceptable plants in accordance with original Specification. Warranty all replaced material for a period of 1 year from date of replacement.

3. Warranty plants for 1 year against all defects of material and workmanship.

4. Any tree and shrub material that is 25 percent or more dead or disfigured shall be considered dead and must be replaced at no charge to Sound Transit. A tree is considered dead when the main leader has died back or there is 25 percent of the crown dead. Plants are considered disfigured when excessive dead wood had been removed or when the symmetry, typical habit of growth, or sculptured form has been impaired by the removal of dead wood.

5. The above warranty is applicable to any growing conditions through which plants of like kind could be expected to survive and any deformity or cause of death which could be attributed to, or affected by, the physiological conditions of the plant. The warranty would not apply to plant losses due to abnormal weather conditions such as floods, excessive wind damage, drought, severe freezing, or abnormal rain, as determined by the National Weather Service.
E. Maintenance shall begin immediately after each plant is planted. Plants shall be watered, mulched, weeded, pruned, sprayed, fertilized, cultivated, and otherwise maintained and protected until the end of the Warranty Period. Tree ties and stakes shall be tightened and repaired as required. Correct defective work as soon as possible after it becomes apparent and weather and season permit. Reset settled plants to proper grade and position, and remove dead material.

F. Watering: Water plants as needed to keep them in a healthy growing condition. The contractor shall be responsible for the watering patterns and timing, including the setting of automatic sprinkler controls. Automatic irrigation systems shall be operated fully automatically during the Warranty Period. Perform automatic watering during the periods of 4 a.m. to 7 a.m. or as otherwise specified. If water restrictions are established, develop watering schedules in consultation with the Resident Engineer. The Contractor is responsible for acquiring a water source for any hand-watering. Before commencement of the Warranty Period, furnish in writing a watering schedule to the Resident Engineer. Any change in watering schedule shall require a minimum 1 working day advance notice to the Resident Engineer. Irrigation system components installed as part of the Work shall be maintained and operated by the Contractor as part of the Warranty Period.

G. Warranty Period also includes maintenance of the planting irrigation system as described in Section 32 84 00, Planting Irrigation and maintenance of the restored lawn areas as described in Section 32 92 00, Turf and Grasses.

H. Mulch: Supplemental mulch shall be applied and replaced in order to return planting areas to conformance with Contract Document requirements. The final mulch application shall be made 1 week before inspection for acceptance.

I. Cleanup and litter removal: Clean up after any work performed by the Contractor during the Warranty Period. Remove all litter in order to provide a clean appearance at the time of Warranty Period inspections.

J. Weed control: Maintain mulched planting areas around trees, shrubs, and groundcovers in a weed-free condition during initial planting and during the Warranty Period. At least 5 working days before the beginning of the Warranty Period submit a weed control plan identifying the means, manner, methods, and timing intervals to ensure weed control. This weed control plan will be subject to revisions dependent on results of the implemented plan.

K. Inspections: Planting areas will be inspected regularly by the Resident Engineer during the Warranty Period. Should the Resident Engineer determine at any time that the Contractor is not providing adequate and proper care of plant material or is performing substandard Warranty Period work, the Resident Engineer will order the Contractor in writing to correct and remedy such unsatisfactory work. The Contractor shall make the necessary correction within a 5 day period immediately following receipt of such notice. In addition to periodic unscheduled inspections of the Work, 4 quarterly inspections will be scheduled to review the conditions of the site during the Warranty Period.

L. Do not prune plants without acceptance of the Resident Engineer.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Soil Amendment Materials

1. Organic Amendments
a. Pure composted plant waste, a well decomposed, humus-like material derived from the decomposition of grass clippings, leaves, branches, wood and other organic materials, as supplied by Cedar Grove, Inc. (877) 764-5748, or Sawdust Supply Co. (888) 622-4321, or accepted equal.

b. Use composted plant waste that is composted for a minimum of 1 year and is composed of 98 percent by volume material derived from the aerobic decomposition of recycled plant waste.

c. Composted plant waste physical criteria:
   1) 100 percent passing through a 1 inch sieve.
   2) pH range between 5.0 and 8.5.
   3) No more than 2 percent foreign material (including plastic, concrete, or metal) on a dry weight basis.
   4) Free of viable weed seeds and other plant propagules (except airborne weed species).
   5) Moisture content that has no visible free water or dust produced when handling material.

B. Topsoil: 3-way topsoil composed as 60 percent sandy loam, 25-30 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) 514-3499, Cedar Grove (877) 764-5748, Sawdust Supply Co. (888) 622-4321, or accepted equal.

C. Sand: Natural, medium to coarse grained in texture, free from salt and decomposed organic matter like roots, sticks, leaves, paper, and of any other undesirable trash like glass, plastic, or metal fragments that could interfere with soil drainage and planting operations.

D. Dolomitic Limestone: Fine ground dolomite with minimum of 88 percent of No 20 sieve retaining 0 percent, and No 100 sieve retaining 25 percent, and packaged in new, waterproof, non-overlain bags, clearly labeled.

E. Water: Potable, clean, fresh, and free from harmful materials. Furnish all hoses and other irrigation equipment required for the Work.

F. Temporary Irrigation Equipment: provide equipment in accordance with accepted temporary irrigation plan.

G. Plants:
   1. Trees and Shrubs:
      a. Provide freshly dug trees and shrubs that are nursery grown in accordance with good horticultural practice for at least 2 years under climatic conditions and soils similar to those at job site.
      1) Trees: Straight trunks with leader intact, undamaged, and uncut.
      b. Appearance shall be typical of species or variety with normal growth habit, in accordance with ASNS.
1) Sound, healthy and vigorous; well-branched and densely foliated when in leaf with healthy root systems, free from disease, insect pests, eggs or larvae, disfiguring knots, sun-scalds, abrasions of the bark, broken tops, torn roots, and any other objectionable feature.

2) Nomenclature: Agree with SPN as accepted in the nursery trade for varieties not listed therein. Clonal types shall be true.

3) Measure height or spread and quality in accordance with standards specified in ASNS (unless otherwise specified).

c. Conform to measurements specified on Plant List. Dimension plants in their natural position. Plants larger than specified may be used, without increasing Contract Price, if approved by the Resident Engineer. Large plants cut back to sizes specified will not be accepted.

d. Provide balled and burlapped stock (B&B) with a compact natural ball of earth firmly wrapped and tied in burlap so that upon delivery the soil in the ball is still firm and compact about the small feeding roots. Root ball sizes shall be in accordance with standards specified in ASNS.

e. Provide container grown stock that is healthy, vigorous, and well-rooted. Plants grown in a container shall have a well-established root system reaching the sides of container and maintain a firm ball when removed from the container. The container shall be rigid enough to hold the ball shape and protect root mass during shipping and be sized according to ANSI Z60.1 for type and size of plant required.

2. Groundcover: Furnish in sizes indicated on the Plant List and conform to ASNS standards for species and sizes.

H. Staking and Guying:


2. Tree Ties: Recycled polyethylene, Dimex ProLock Poly Chain Lock, or accepted equal.

3. Twine: 3-ply jute.

I. Mulch:

1. Organic Mulch: Fine fir or hemlock bark of uniform color for use in planting or tree and shrub saucers; free from weed seed, sawdust and splinters; not containing resin, tannin, wood fiber or other compounds detrimental to plant life.

   a. Bagged mulch: Moisture content not in excess of 22 percent.

   b. Bulk mulch: Size range of 1/2 inch to 1-1/4 inch with a maximum of 20 percent passing a 1/2 inch screen

2. Gravel Sedum Mulch: Hydrotech Design Roof Garden LiteTop Soil Mix, or accepted equal.

J. Fertilizers:
1. General: Packaged in new, waterproof, non-overlaid 80 pound bags clearly labeled as to weight.

2. Fertilizer to be commercial grade, containing not less than 10 percent Nitrogen, 6 percent phosphorous and 4 percent potash by weight of ingredients.

K. Plant Treatment Materials:

1. Anti-desiccant: Wiltpruf as manufactured by Wiltpruf Products, Inc., PO Box 4280, Greenwich, CT. 06830, (203) 531-4740; Moisturin as manufactured by GSI Horticultural, 141 NW Greenwood Ste. 200, Bend, OR 97701, (541) 383-0222. Fax: (541) 388-2351 (http://www.gsihorticultural.com/products.shtml); or Vapor Guard as manufactured by Miller Chemical & Fertilizer Corp., PO Box 333, Hanover, PA 17331, (717) 632-8921 (www.millerchemical.com), or accepted equal.

2. Mycorrhizae: Mycogrow Gel as manufactured by Fungi Perfecti, Olympia, WA, (800) 780-9126; Mycorrhizal Landscape Inoculant as manufactured by BioOrganics, Santa Monica, CA, (888) 332-7676; or Biovam as manufactured by Brock Probiotics and available through T&J Enterprises, Spokane, WA (509) 327-7670, or accepted equal.

2.02 SOURCE QUALITY CONTROL

A. Plant Material: Provide plants of quantity, size, genus, species, and variety as indicated in the Construction Documents for landscaping work and complying with recommendations and requirements of ASNS. Provide healthy, vigorous stock, grown in recognized nurseries in accordance with horticultural practice and free of disease, insects, eggs, larva, and defects such as knots, sun-scald, injuries, abrasions, or disfigurement.

B. Plant List: In accordance with Submitted Source of Supply Plan.

C. Substitutions: Substitutions will not be permitted unless substantiated written proof is supplied that a specified plant is not obtainable. In this situation, submit a proposal to use the nearest equivalent size or variety with an equitable adjustment of the Contract for acceptance by Resident Engineer.

D. Contractor: Perform work with personnel familiar with planting techniques under the supervision of experienced landscape forepersons at all times. Notify the Resident Engineer of the name and phone number of the forepersons 5 business days in advance of the first day of planting operations.

PART 3 - EXECUTION

3.01 EXAMINATION

A. Prior to preparation of planting areas, ascertain the location of all electric cables, conduits, underdrainage systems and utility lines. Take proper precautions to not disturb or damage sub-surface elements. If sub-surface elements are uncovered, promptly notify the Resident Engineer. Contractor is responsible for making requisite repairs to damaged utilities at his own expense if this procedure is not followed.

1. Verify that required underground utilities are available, in proper location, and ready for use. Coordinate with other trades.

2. Verify that subgrades are at lines and grades appropriate to provide specified depth of prepared planting soil.
3.02 PREPARATION

A. Refer to Section 01 56 39, Temporary Tree and Plant Protection for construction within CRZ areas.

B. Protection of existing conditions:
   1. Use every possible precaution to prevent damage to existing conditions to remain, such as structures, utilities, plant materials, and walks on, or adjacent to, the site of the Work.
   2. Provide barricades, fences, or other barriers to protect existing conditions to remain from damage during construction.
   3. Do not store materials or equipment, permit burning, or operate or park equipment under the branches of existing plants to remain.
   4. Submit written notification of damaged plants and structures to the Resident Engineer immediately.

C. Preparation of planting and lawn areas:
   1. Subgrade preparation:
      a. Completely remove and dispose of all structural fill, gravel, quarry spall, constructions debris, and other obstructions in the area to receive planting to a minimum depth of 24 inches, including areas where native soils have been removed and replaced with structural materials adjacent to buildings and paved areas. Remove debris and rocks over 4 inches in size to a depth of at least 24 inches in all areas to receive planting.
      b. If native soil in areas to receive planting is free from structural fill, gravel, quarry spall, construction debris, and other deleterious materials, establish subgrade lines and grades appropriate to provide for specified depth of prepared planting soil.
      c. If subgrades need to be raised to establish lines and grades appropriate to provide for specified depth of prepared planting soil use accepted Nonstructural Fill as defined in Section 31 20 00, Earth Moving.
      d. After subgrade lines and grades are established, scarify exposed soils to a depth of at least 24 inches. Moisture condition if necessary. Compact to 85 percent maximum of dry weight density.
      e. Finish subgrades will be inspected and accepted by Resident Engineer before installation of soil.
   2. Soils in planting areas:
      a. In planting areas on native soil: Provide 12 inches of topsoil in two 6 inch lifts. Place first lift and rototill into top 12 inches of native soil. Place second lift and rototill into top 12 inches of soil.
      b. In planting areas on fill: Provide 18 inches of topsoil in three 6 inch lifts. Place first lift and rototill into top 6 inches of scarified fill. Place second lift and rototill into top 12 inches of soil and fill. Place third lift and rototill into top 12 inches of soil.
c. In areas that are protected by vegetation protection fencing or are beneath the canopies of existing trees and shrubs, whichever area is greater, perform soil preparation under the direction of the Resident Engineer and the Project Arborist. Loosen native soil by hand using a shovel or fork to avoid loosening or damaging the root systems of existing trees and shrubs. Spread a 2 inch layer of topsoil over native soil. Incorporate topsoil into native soil using a shovel or fork. Feather prepared planting soil grades into adjacent grades outside existing tree and plant canopies.

d. In areas where dense clay native soil material is encountered, spread a 2 inch layer of sand over the native soil and rototill into the top 12 inches of native soil prior to installation of topsoil.

e. Ensure prepared planting soil is free of stones, clods of earth larger than 1 inch in diameter and other deleterious matter.

f. Apply dolomitic lime to all planting areas as required to obtain a pH range of 6.0 to 6.5 (Exception: Do not apply lime to ericaceous planting areas.) Do not apply more than 60 pounds of lime per 1,000 square feet at one time. Verify pH by test of each major planting area.

g. Roll or hand compact prepared planting soil to achieve compaction of 85 percent of dry weight density.

h. Mix additional amendments into the soil as recommended by the testing laboratory per Article 1.04H, and accepted by the Resident Engineer.

i. Incorporate amendments thoroughly into the native soil to assure uniform distribution.

3. Obstructions below grade: In the event that roots, rocks, underground construction work, utilities, or obstructions are encountered during discing and tilling operations under this Contract, continue mixing by hand with shovel or fork.

D. Finish grading:

1. After natural settlement and light rolling, complete work to conform strictly to the lines, grades and elevations indicated. Elevations and landform configuration is critical to project design intent. Supply additional soil as needed to give the specified depths and grade.

2. Grades in planting areas not otherwise indicated shall have uniform levels or slopes between points established by pavements, curbs, catch basins or other utility lids. Finish grade shall be smooth, even and on a uniform plane with no abrupt change in surface and have no erosion scars.

3. Slope all planting areas to drain. If drainage conditions are questionable, request inspection and direction from the Resident Engineer. Adjustments to accommodate drainage concerns must be approved by the Resident Engineer. Drainage problems discovered after plant material is installed shall be corrected to the satisfaction of the Resident Engineer as part of the Contract.

4. Ensure finish grading accounts for depth of mulch in relation to adjacent grade conditions.

5. Protect all planting areas against compaction by construction equipment.
E. Planting layout:

1. Stake out new planting where shown on Construction Documents except where obstructions exist below ground, overhead, or where changes have been made during construction. Complete layout of planting beds, plants and pits before seeking acceptance by the Resident Engineer.

2. Coordinate layout and installation of plant material with installation of the irrigation system to ensure that there will be complete and full irrigation coverage of the planting areas.

F. Planting backfill:

1. Where planting pits exceed the depth of prepared planting soil, mix 50 percent native topsoil dug from planting pit with 50 percent topsoil as shown in planting details.

3.03 PLANTING INSTALLATION OF TREES, SHRUBS, AND GROUNDCOVERS

A. Excavation:

1. Excavate all plant pits in accordance with the Contract Drawings after acceptance of staked locations by the Resident Engineer. Excavate plant pits only after prepared planting soil has been tested, analyzed, amended, and accepted by the Resident Engineer.

2. Excavate pits and beds with sloping sides and with the pit bottom’s center raised for holding rootball. Loosen sides and bottoms by scarifying.

3. Excavate pits and beds within branch spread of existing trees and shrubs by hand. Notify Resident Engineer immediately if dense root mats or structural or feeder roots are encountered. Resident Engineer will make adjustments to planting locations if new planting excavation will potentially adversely impact existing plant material.

4. Fill tree pits with water prior to planting to test drainage. Resident Engineer shall inspect and accept plant pits prior to planting. If Resident Engineer determines that drainage is not satisfactory to healthy plant growth, additional excavation and drainage efforts must be made at direction of Resident Engineer.

5. Underground Obstructions: In the event that rock, underground construction work, utilities or obstructions are encountered in any plant pit excavation work under this Contract, alternate locations may be selected by the Resident Engineer.

6. Where locations cannot be changed, remove the obstruction, subject to the Resident Engineer approval, to a depth of not less than three feet below grade and no less than six inches below bottom of ball or roots when plant is properly set at the required grade. Payment shall be made in accordance with the Contract.

B. Inoculation:

1. Inoculate balled and burlapped plants and container plants with mycorrhizae in accordance with manufacturer’s recommendations.

C. Placement of plants:
1. Set plants in centers of pits plumb and straight, in accordance with the planting details, and faced to give best appearance and relationship to adjacent plants and structures.

2. Do not plant until the Resident Engineer at site has reviewed and accepted plant material on-site.

3. Check top of tree and shrub root ball for root flare. If roots are not found, the Contractor shall scrape away excess root ball soil until root flare is exposed.

4. Plant to such depth that the finished grade level of the plant, after settlement, will be the same as that at which the plant was grown and indicated by the root flare.

5. Do not pull burlap out from under balls, but peel back 2/3 of burlap covering, cut along base, and remove. If root ball wrap is non-biodegradable, remove completely. Remove platforms, wire, and surplus binding from top and sides of ball. Cleanly cut off all broken or frayed roots. Tease out existing roots on perimeter of root ball without disturbing structure of root ball. Cut all girdling roots.

6. Clip and remove wire basket from top and sides of rootball.

7. Remove plants from containers by cutting or inverting the container.

8. Backfilling:
   a. Do not backfill plant pits until the Resident Engineer has accepted them.
   b. Compact planting backfill around bases of root balls to fill all voids. Remove all non-biodegradable materials from the plant pit.
   c. Install planting backfill in layers of not more than 6 inches. Thoroughly compact by hand to ensure planting backfill is free of voids before next layer is installed.
   d. Water thoroughly until the root ball and planting pit is saturated.

D. Mulching:
1. Furnish all equipment and labor to load, haul, and place mulch. Mulch within 2 days of planting. Cover tree and shrub beds with a continuous layer of mulch. Keep mulch 3 inches away from tree and shrub root flare.

E. Hydroseeding: as specified in Section 32 92 00, Turf and Grasses.

F. Sowing Sedum Cuttings:
1. Cuttings shall be evenly distributed across the planting area at a rate of 30 cuttings per square foot.

2. To ensure diversity and survivability species and cultivars shall be an even distribution as specified in Contract Documents.

3. Do not sow until the Resident Engineer at site has approved plant material and layout.

4. For areas of sowing, water gravel sedum mulch thoroughly before sowing.
5. Watering: Upon completion of Sedum cutting sowing, water plant material thoroughly. Apply water slowly so as to penetrate the soil system and at a rate which will prevent saturation of the soil. Do not disturb layout and distribution of plant material during watering. Sedum cuttings will require watering 4 times per day until they establish roots. After root establishment, water once per week until plants are established.

3.04 REPAIR AND RESTORATION

A. Pruning:

1. Remove dead or broken branches with a clean cut, in a manner appropriate to the particular requirements of each plant, and at the time designated by, and to the satisfaction of, the Resident Engineer. Perform pruning with clean, sharp tools.

2. Promptly trace and treat accidental damage to trees and shrubs occurring during the course of planting operations which is not so great as to require removal of a branch or the replacement of the plant in accordance with recognized horticultural practices as directed by the Resident Engineer.

B. Watering: Upon completion of planting operation, water plant material thoroughly. Apply water slowly to penetrate and saturate the entire root system while avoiding runoff.

C. Restoration of existing vegetation: Restore native soil, plant material and mulch to a condition equal to that at the commencement of construction, as indicated herein.


3.05 PROTECTION

A. Guying and staking:

1. Stake or guy trees as detailed to stand plumb immediately after planting.

2. Remove and replace damaged stakes. Any tree or shrub thrown out of plumb by wind action or other causes shall be replanted by loosening the soil around the root system and righting the tree or shrub by adjusting the position of the root system. Adjustment shall not be made by pushing or restraining the trunk or stem. If, in the opinion of the Resident Engineer, damage to the root system has occurred as a result of righting a tree or shrub, the tree or shrub shall be replaced by the Contractor.

B. Plant protection fence:

1. For protection of new plantings and lawns from work by other trades or from use by the public, provide fences in areas not already protected by temporary tree and landscape fencing.

2. Prior to installation, stake location of fence as approved by Resident Engineer. Coordinate location and type of fence with planting work so that planting will not be damaged by installation of fence. Install posts plumb. Tie fence taut. Coordinate removal of fence with Resident Engineer.
3.06 ADJUSTING AND CLEANING

A. Maintain the site in an orderly condition during the progress of the Work. Continuously and promptly remove excess and waste materials; keep lawn areas, walks, and roads clear. Store materials and equipment where directed. Immediately remove rejected materials from the site. Promptly remove equipment, surplus material, debris and trash resulting from operations under this Contract upon completion and prior to initial acceptance of Work. Leave the site in a neat, orderly condition, broom clean.

B. Protect landscape work and materials from damage due to landscape operations, operations by other contractors, trades, and trespassers. Maintain protection during installation and maintenance periods. Provide adequate and proper care of all plant material and work done on this project until the Contract is completed and accepted by the Resident Engineer. Adequate and proper care means keeping all plant material in a healthy, growing condition and also includes removing the weeds, litter, and other debris along with retaining the finished grades in a neat uniform condition.

3.07 WARRANTY PERIOD AND FINAL ACCEPTANCE

A. Maintain plant materials from the time of planting until the plant materials are well established and are exhibiting a vigorous growth. Maintenance shall continue until the end of the Warranty Period as specified in Article 1.14 herein.

B. Final inspection will be conducted at the end of the Warranty Period. Submit notice to the Resident Engineer requesting final inspection at least seven days prior to the anticipated inspection date.

C. Apply granular form commercial fertilizer to all planting areas in accordance with the manufacturer’s application rates 5 days prior to the final inspection. Prevent the deposit of fertilizer on plant stems or leaves. Apply fertilizer only during favorable weather conditions to prevent dissipation by wind. Thoroughly water plants after fertilizer has been applied.

D. Prior to final inspection, thoroughly weed and clean planting areas.

E. At the final inspection, the Resident Engineer will determine the condition of the plants and improvements. Acceptance of this Work will be contingent upon proper maintenance and the establishment of vigorous plant materials. Plans which are dead, unhealthy, or missing, whether by disease, neglect, vandalism, or any other reason, shall be replaced with the same species and sizes originally specified and following the same specifications for installation.

F. Provide plant replacements within 2 weeks after final inspection, and extend the Warranty Period for an additional 30 days after replacement planting has been accepted by the Resident Engineer. The Resident Engineer will then repeat the final inspection for the replaced plants at the end the extended Warranty Period.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 32 92 00
TURF AND GRASSES

PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing all materials, equipment, and labor necessary for preparation, seeding, fertilizing, mulching, and protection of hydroseeded areas of lawn.

B. This Section also includes maintenance of the restored lawn areas during the 90 day Lawn Establishment Period.

1.02 RELATED SECTIONS

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 01 56 39, Temporary Tree and Plant Protection.
2. Section 31 20 00, Earth Moving.
3. Section 31 11 00, Clearing and Grubbing.
4. Section 32 84 00, Planting Irrigation.
5. Section 32 90 00, Planting.

1.03 SUBMITTALS

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

B. Product Data: grass seed mixture, hydromulch, and soil binding agent.

C. Certifications:

1. Submit seed vendor's certification for required grass seed mixture, indicating percentage by weight and percentages of purity, germination, and weed seed for each grass species.

1.04 QUALITY ASSURANCE

A. Landscape Contractor: A single firm licensed in the state of Washington with at least 5 years experience on projects of similar scope and experienced in landscape work of the highest professional quality. Firm must have equipment and personnel adequate to perform the work specified.

B. Furnish seed in containers that show: seed name, lot number, net weight, percentage of purity, germination, weed seed, and inert material. Seed that has become wet, moldy, or otherwise damaged will not be accepted. Use seed that is “certified” grade or better,
conforms to the requirements of the Washington State seed law and, when applicable, the Federal Seed Act.

1.05 DELIVERY, STORAGE, AND HANDLING
A. Deliver seed and fertilizer materials in original, unopened containers showing weight, analysis, and name of manufacturer. Store seed in such a manner that prevents wetting and deterioration.

1.06 FIELD QUALITY CONTROL
A. Grading Inspection:
   1. Subgrades: Inspected and approved by the Resident Engineer prior to placing topsoil.
   2. Finish grading: Inspected and approved by the Resident Engineer prior to seed application.
B. Inspections:
   1. Request a provisional inspection by the Resident Engineer upon completion of the work. Upon completion of the punch list, the Resident Engineer will make provisional acceptance in writing.
   2. Final acceptance will be at the end of the Lawn Establishment Period, and after all required repairs have been made.

1.07 WARRANTY AND REPLACEMENT
A. Seeded areas shall have a relatively uniform stand of grass with no bare spots over 12-square inches at the time of provisional acceptance. Reseed at the original rate and fertilize with 10-20-20 at the rate of 20 pounds per 1000 square feet of blended materials. All areas failing to vigorously establish within 90 days after germination or 1 growing season (whichever is longer), for any reason whatsoever, shall be reseeded at no cost to Owner.
B. The Lawn Establishment Period begins after Substantial Completion as granted by the Resident Engineer with written notification.

1.08 JOB CONDITIONS
A. Environmental Requirements: Do not plant when the ground is frozen, or the soil is otherwise in an unsatisfactory condition for planting and hydroseeding. Do not plant during periods of excessive heat, drought, moisture and cold.

PART 2 - PRODUCTS

2.01 SOIL AMENDMENTS, LIME, AND FERTILIZERS
A. Provide the following:
   1. Organic Amendment.
   2. Dolomite Lime.
   3. Fertilizers.
2.02 HYDROMULCH
A. Wood cellulose fiber from Alder; containing a soil-binding agent (tackifier); dyed a suitable color to facilitate placement; and containing no growth or germination inhibiting substances.

2.03 SOIL BINDING AGENT (TACKIFIER)
A. Non-toxic, biodegradable materials that are environmentally safe such as ESI - TAK or approved equal. Materials must be manufactured in such a manner that after addition and agitation in slurry tanks with fertilizers, grass seeds, water and other improved additives, the fibers in the material will become uniformly impregnated with grass seed, and which after application, will allow the absorption and percolation of moisture. Each package of the cellulose fiber shall be marked by the manufacturer to show the air-dry weight content. Wood cellulose fiber shall be utilized as mulch and applied with seed and fertilizer in 1 operation by approved hydraulic equipment.

2.04 SEED MIXES
A. Seed: Seed shall be fresh, clean, new crop seed. Seed mixes shall be Washington or Oregon certified. All other crop shall be identified. The Contractor shall furnish to the Resident Engineer the dealer's guaranteed statement of the composition of the mixture and the percentage of purity and germination of each variety. Seed shall not contain in excess of 1.0 percent weed seed. Seed containing prohibited or restricted noxious weeds will be rejected. The following noxious weeds are prohibited from any mix: Bindweed, Canada Thistle, quackgrass, sedge kind weed, horse nettle, wild garlic, Bermuda grass, cheat, wild onion, corn cockle, dodder, Johnsongrass, perennial sweet Sudan grass, sorghum hybrids.

B. Seed Mix:

<table>
<thead>
<tr>
<th>Name:</th>
<th>Percent by Weight</th>
<th>Percent Purity</th>
<th>Percent Germination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magic Chewings Fescue</td>
<td>30</td>
<td>98</td>
<td>92</td>
</tr>
<tr>
<td>Hard Fescue</td>
<td>20</td>
<td>98</td>
<td>91</td>
</tr>
<tr>
<td>Durby Perennial Ryegrass</td>
<td>50</td>
<td>98</td>
<td>98.25</td>
</tr>
</tbody>
</table>

2.05 SOILS
A. As specified in Section 32 90 00, Planting.

PART 3 - EXECUTION

3.01 SOIL PREPARATION
A. Refer to Section 01 56 39, Temporary Tree and Plant Protection for construction within CRZ areas.

B. Perform all soil preparation operations, compaction, and clean up of debris prior to seeding.
3.02 CULTIVATION
A. Perform soil cultivation in conjunction with the requirements of Section 32 90 00, Planting. Cultivation may be done by farm disc, harrow or other suitable equipment approved by the Resident Engineer. Prior to cultivation, apply dolomite limestone at the rate of 8 pounds per 1000 square feet and cultivate to a depth of 4 inches.

3.03 SOIL PLACEMENT
A. Place soil in conjunction with the requirements of Section 32 90 00, Planting. Spread amendments or prepared soils evenly in the locations and to the depths indicated. After soil has been spread, remove all large clods, rocks and debris greater than 1 inch in any dimension. Do not place soil when the ground is frozen, wet or in a condition detrimental to the work.

3.04 COMPACTION
A. Compact with sheep's foot roller, cleated crawler tractor, vibratory roller, or equipment approved by the Resident Engineer. Use equipment to produce 150-300 pounds per square foot of ground pressure.
B. Compact to produce a uniform, rough textured surface free of tire ruts, depressions and low spots, and ready for seeding and mulching. Make a minimum of 4 passes. After compaction, finish grade to be flush with the top of curbs, catch basins and other structures.

3.05 WATERING
A. If required by the Resident Engineer, provide water to condition the soil for compaction or to provide dust control. Furnish water from on site or by watering truck.
B. Provide temporary irrigation to all hydroseeded areas as indicated in the Contract Documents and as specified herein and in accordance with the temporary irrigation plan required by Section 32 90 00, Planting.
C. Commence watering immediately to begin establishment of lawn. Watering and fertilizing shall be the Contractor's responsibility during the Lawn Establishment Period.

3.06 SEEDING
A. Apply fertilizer, seed and mulch in 1 operation with approved hydraulic equipment. Apply materials at the following rates:
   1. Hydromulch, at 50 pounds per 1,000 square feet.
   2. Seed, at 9 pounds per 1,000 square feet.
   3. Lawn Starter Fertilizer, at 20 pounds per 1,000 square feet.
   4. Soil Binding Agent, at 1 pound per 1,000 square feet.
B. Do not perform seeding during windy weather (above 25 mph) or when the ground is saturated or frozen. Give the Resident Engineer 48 hours notice of seeding operations. Perform seeding, fertilizing, and mulching of prepared areas during the following time frames:
   1. Seeding: from April 1 to June 15th or from September 1 to October 31.
   2. Do not seed before or after these dates without written approval of the Resident Engineer. Written permission to seed from June 1 to August 31 may be granted...
only if automatic irrigation is available and operational at the site. Permission to seed from November 1 to March 31 will only be given when completion of the Contract is imminent and the environmental conditions are conducive to acceptable growth. Do not perform seeding on weekends or legal holidays without written approval of the Resident Engineer.

3. Application of pre-germinated seed, moisture retention agents and/or provision for supplemental watering may be required by the Resident Engineer should the Contractor schedule this portion of the Work outside the time frames listed in Article 3.06B.1, herein.

4. All areas must be prepared and seeded during the first available planting period and shall not be allowed to sit idle for long periods of time without receiving the erosion control specified in the Contract.

5. When environmental conditions are not conducive to acceptable results from seeding operations, the Resident Engineer may order the Work suspended. Resume Work only when the desired results are likely to be obtained.

6. Areas inaccessible to above methods of application shall be seeded and fertilized by approved hand methods. Distribute material uniformly and at the rates specified.

7. Notify the Resident Engineer not less than 48 hours in advance of seeding operation. Do not begin the work until areas prepared or designated for seeding have been accepted. Following acceptance, immediately begin seeding and fertilizing of the approved areas.

8. Reseed and fertilize all areas failing to show a uniform stand of grass after germination of seed, or damage through any cause before final inspection. Reseed areas which fail to show a uniformly thickness until all areas are covered with a satisfactory growth of grass. Hydroseeded areas shall show no dead spots at Substantial Completion and shall be anchored to topsoil bed with vigorous, healthy root growth. Prior to Substantial Completion, damage resulting from erosion, gullies, washouts or other causes shall be repaired by filling with topsoil, tamping, re-fertilizing.

C. Provide qualified personnel experienced in all phases of the seeding and fertilizing operation, equipment and methods as herein specified.

D. Equipment: use a continuous, built-in agitation system that uses water as a carrying agent. Equipment with a gear pump is not acceptable.

E. Pump a continuous, non-fluctuating supply of homogenous slurry to provide a uniform distribution of material over designated areas.

3.07 MAINTENANCE

A. Provide water for temporary irrigation plan as specified in Section 32 90 00, Planting.

B. Begin maintenance immediately after each portion is installed and continue for 90 growing season days after Substantial Completion of all Work. Growing Season is defined as April 15 to November 15. Maintenance includes re-seeding, repair of ruts and erosion, repair of protective devices, watering, weeding, cutting and the repeating of any or all phase of seeding construction that may be required to obtain a uniform, thick and well developed stand.

C. Bare or dead spots that are smaller than 36 square inches shall be allowed up to a maximum of 2 percent of any seeded area after initial installation. After the seeded plants have been
established, all areas which fail to show a uniformly thick and well-developed stand, including base or dead spots, shall be reseeded repeatedly until all areas are covered with a satisfactory growth of grass. Hydroseeded areas shall show no bare or dead spots at Substantial Completion and shall be anchored to soil with vigorous, healthy root growth. Prior to Substantial Completion, damage resulting from erosion, gullies, washouts, or other causes shall be repaired by filling with topsoil, tamping, and re-fertilizing.

D. After the first mowing, fertilize turf with specified (16-16-16) Maintenance Fertilizer for lawns and athletic fields, at the rate of 2 pounds per 1,000 square feet of blended materials.

E. Remove all grass clippings from the site.

3.08 SUBSTANTIAL COMPLETION

A. Inspection to determine Substantial Completion of seeded areas will be made by the Resident Engineer upon the Contractor’s request. Provide notification at least 5 working days before requested inspection date.

1. Seeded areas shall be accepted provided all requirements, including maintenance, have been complied with and grass is well established and exhibits a vigorous growing condition.

2. Reseed areas failing to show a uniform stand of grass at no cost to Sound Transit.

3.09 LAWN ESTABLISHMENT

A. Lawn Establishment shall consist of providing adequate and proper care for public and private lawn areas installed within this Contract. The Lawn Establishment Period shall begin upon acceptance of Substantial completion by the Resident Engineer based upon a uniform stand of grass and based on the first mowing. The Lawn Establishment Period shall extend for a minimum of 90 days.

B. During the Lawn Establishment Period provide adequate and proper care to ensure the continuing healthy growth of the lawn. Adequate and proper care shall include the labor, materials, and equipment necessary to keep the lawn areas in a presentable condition including mowing, watering, trimming, removal or adequate mulching of grass clippings, litter or debris removal, edging, fertilizing, weed control, repair and reseeding damage areas, and repairing and maintenance of irrigation systems installed as part of the Work.

C. During the Lawn Establishment Period, the Contractor shall satisfy the following minimum requirements:

1. Erect temporary barriers, with warning signs where necessary, to preclude pedestrian traffic across new installed lawn areas. Remove temporary barriers after the grasses have developed into a heavy sod mat and only on written permission from the Resident Engineer.

2. Mowing and edging shall be done as often as conditions dictate. Maximum height of the lawn shall not exceed 3 inches. The cutting height shall be 2 inches with all cuttings mulch-mowed and left on the lawn unless otherwise approved by the Resident Engineer.

3. A slow release form of nitrogen fertilizer shall be applied at the end of the Lawn Establishment Period. Rate of application and formulation in accordance with Article 3.07D herein.

4. Provide watering to allow for vigorous growth of the lawn. Adjust the rate and frequency of watering depending on the weather and soil conditions.
5. The lawn will be inspected regularly by the Resident Engineer during the Lawn Establishment Period. Should the Resident Engineer determine at any time that the Contractor is not providing adequate and proper care of the lawn or is performing substandard lawn establishment Work, the Resident Engineer will order the Contractor in writing to correct and remedy such unsatisfactory Work or practices. The Contractor shall make the necessary corrections within a 5 day period immediately following receipt of such notice.

6. Final Acceptance of the lawn shall be based on a uniform stand of grass at uniform grade at the end of the Lawn Establishment Period. Areas that are bare, have a poor stand of grass, or do not have a uniform grade, shall be re-graded, re-seeded and re-fertilized. If corrections are required after the inspection for Final Acceptance, the Lawn Establishment Period will be extended an additional 45 days, shall include all the Lawn Establishment Period maintenance requirements, and shall be re-inspected.

3.10 CLEANING

A. Perform cleaning during installation of the work and upon completion of the work. Remove from the site all excess materials, soil, debris, and equipment. Repair the damage resulting from seeding operations.

END OF SECTION
CONTRACT SPECIFICATIONS

SECTION 33 01 00
OPERATION AND MAINTENANCE OF UTILITIES

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.

C. 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 such as Seattle Public Utilities call the affected utility owners directly.

2. To locate utilities on the University of Washington campus, contract directly with APS (Applied Professional Service, Inc.) to field locate all existing utilities on the University of Washington property.

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 immediately for corrective action.

F. Perform due diligence to repair any damage to University of Washington utilities within 24 hours of impact.

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 on the University of Washington property and 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 78 23, Operation and Maintenance Data
2. Section 02 41 00, Demolition
3. Section 31 23 19, Dewatering
4. Section 31 23 33, Trenching and Backfilling
5. Section 33 01 00, Operation and Maintenance of Utilities

1.02 REFERENCES

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

   a. ASTM B62, Standard Specification for Composition Bronze or Ounce Metal Castings

2. 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, Installation of Ductile-Iron Water Mains and Their Appurtenances
k. AWWA C651, Disinfecting Water Mains
l. AWWA C703, Cold-Water Meters - Fire Service Type

3. City of Seattle (COS):
   a. Standard Specifications for Road, Bridge and Municipal Construction
   b. 2006 Seattle Fire Code

4. Factory Mutual “Approval Guide”

5. National Fire Protection Association (NFPA):
   a. NFPA 24, Standard for the Installation of Private Fire Service Mains and their Appurtenances

6. National Sanitation Foundation (NSF)


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.

D. General: Refer to Section 01 77 00, Closeout Procedures, and Section 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 complying with Section 01 45 00, Quality Control. An approved Construction Work Plan is a precondition for the Readiness Review Meeting.

1. Attend a Readiness Review meeting with representatives of Sound Transit and the University of Washington to determine roles and responsibilities for the tasks and timing of the work to be incorporated into the Construction Work Plan.

2. Provide a written estimate of duration and date of shutdowns to the Resident Engineer a minimum of 14 Working Days prior to desired shutdown. Shutdowns are subject to University of Washington Fire Protection Engineer’s approval.
1.04 QUALITY ASSURANCE

A. Regulatory Requirements:

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, testing, 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.

1.06 PROJECT CONDITIONS

A. Sequencing and Scheduling: Include sequencing and scheduling information in the Construction Work Plan, refer to Article 1.03F, herein.

B. Inspection: Inspect pipe before it is installed. Remove defective products from the Project Site.

C. Protection:
   1. Prevent water from entering trenches and excavations.
   2. Other than chlorination chemicals and 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.

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:
   a. Centrifugally cast in 18-feet nominal lengths marked conforming to AWWA C151.
   b. Cement-mortar lining conforming to AWWA C104.
   c. Standard Thickness Class 52.
   d. Non-restrained joints: Use rubber gasket, push-on type, or mechanical joints conforming to AWWA C111.
   e. Restrained Joints: 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. 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.
   g. Restrained Joints: Boltless design which is flexible after assembly and can be disassembled without special tools. Joints 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.

4. 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.

C. Polyethylene Tubing: Ensure that the polyethylene tubing meets the requirements of AWWA C901. Tubing is to have a high molecular mass and a minimum of a 200 psi rating. For 1 ½-inches and 2-inches tubing use SDR 9 (copper tube size).

D. Service Fittings: Use fittings for polyethylene tubing of either compression or stab type. Use an internal grip ring and O ring seal on stab type fittings. Use stainless steel liners when utilizing compression fittings on polyethylene tubing. Provide fittings that are rated for a minimum of 200psi.

E. 2" Private Domestic Water Meter: Meets or exceeds requirements of ANSI/AWWA C701 for Class II Turbine meters. Meter case constructed of ductile iron which is fusion-bonded epoxy coated complying with NSF standards. Ensure that the meter system includes a meter strainer. Ensure that the meter is rated to operate up to 200psi. Ensure that the meter system is equipped with a local display register. Meter recommendation is the Sensus Metering Systems OMNI T2 or approved equal.

F. 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”. Valves to be listed by Underwriters Laboratories, Inc and approved by Factory Mutual Research Corp.

G. 2-inch manual gate valve for irrigation: Provide a bronze valve conforming to ASTM B62 with bronze solid wedge, integral taper seats and a non-rising stem.


I. Fire Meter Assembly: Class II turbine type meter with fire service strainer complying with the following requirements:


2. Meter assembly operating range up to 2,000 gallons per minute (gpm) and a pressure loss at 2,000 gpm of 6.8 pounds per square inch (psi) or less.

3. Meter rated to operate properly without leakage, damage or malfunction up to a maximum pressure of 175 psi.

4. Ensure that the meter is Underwriter’s Laboratory (UL) listed and that the casing bears the UL mark.

5. Ensure that the meter is equipped with an internal straightening vane in the inlet portion of the maincase.

6. Equipped with a totalizing flow register which is hermetically sealed and has a low flow indicator.

7. Strainer: Ductile iron Underwriter’s Laboratory (UL) listed external fire service strainer with a screen having a minimum net open area of four times the pipe opening and be V-shaped stainless steel. Ensure that the strainer bears the UL listing mark on the casing.

J. Backup Fire Service Meter Vault: Utility Vault company’s 712-CLX or approved equal. Lid equipped with two door, galvanized diamond plate covers, spring assisted with locking latch.
K. Concrete Thrust Blocking: Constructed of Class 5 (1-1/2) concrete in accordance with COS Specification Section 5-05.3.

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)A.

H. Protection:
   1. Prevent water from entering trenches and excavations.
   2. Other than chlorination chemicals and 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. 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.

C. 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.

D. 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.

E. AWWA Gate Valves: Comply with AWWA C600 and AWWA M44. Install each underground valve with stem pointing up and with valve box.

F. Minimum depth of cover over the pipe is 36 inches.

G. Concrete Thrust Blocking: City of Seattle Specification Section 7-11.3(13).

H. Connections for University of Washington owned Water Mains:

1. Flush, pressure test and disinfect newly installed Water Main. Perform bacteriological test and ensure that the results are acceptable in accordance with Article 3.03, herein, before making any connections to existing mains

2. 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.

3. The Contractor’s scheduling of connections requires the Resident Engineer’s approval. Refer to the Construction Work Plan, Article 1.03F, herein.

4. The Contractor is responsible for making connections to existing water mains and will operate all valves to accomplish shutdowns and subsequent reactivation.

5. The Contractor is responsible for draining existing water mains

6. The excavation for the connection shall be completed, shored, and dewatered, and all required materials and equipment shall be available at the time of shutdown. Furnish and install the connection fittings in accordance with the City of Seattle Standard Plan 300 with the exception that all references to “SPU” are replaced by “Contractor.”

3.03 FIELD QUALITY CONTROL

A. Testing of University of Washington owned Water Mains and appurtenances:

1. Notice of Testing:
   a. Give 48 hours notice to the Resident Engineer as to the date and time of flushing, pressure testing, and bacteriological testing.
   b. Do not perform testing unless witnessed by the Resident Engineer, University of Washington Fire Protection Engineer and a representative from the Seattle Fire Department.

2. Testing Requirements:
   a. General:
1) Test per AWWA and NFPA 24 requirements.

2) Furnish, install, and operate pumps, gauges, meters, plugs, miscellaneous hose and piping, and measuring equipment necessary to perform the tests.

3) Maintain isolation of the portion of pipeline being tested throughout the performance of leakage and pressure testing.

4) Where valves are used for isolation, eliminate leakage through valves if it occurs. Maintain new work isolated from existing water mains, except for test connections, until testing and sterilization have been completed.

5) Dispose of treated water flushed from the water mains in a manner acceptable to state and local authorities. Neutralize water before disposal into any natural drainage channel. If discharge to the sewer system is accepted by the Resident Engineer, maintain an air gap of 12 inches between the discharge outlet and the overflow rim of the receiving waters.

b. Hydrostatic Tests:

1) Perform hydrostatic tests per the requirements of NFPA 24.

2) Backfill the pipeline sufficiently to prevent movement of the pipe under pressure. Do not backfill joints. All joints must be clearly visible for inspection and monitoring during testing.

3) Do not test until concrete thrust blocks have cured. Where permanent blocking is not required, furnish and install temporary blocking and remove it after testing.

4) If the tested section fails to meet the pressure test successfully as specified, locate and repair the defects and retest the pipeline at no additional cost to Sound Transit.

5) Prior to calling out the witnesses to the pressure test, have all equipment set up completely ready for operation and perform the pressure test once to ensure that the pipe is in acceptable condition.

c. Flushing:

1) Flush water main prior to making any connections to existing mains.

2) Comply with the requirements of NFPA 24 for flushing of mains.

d. System Disinfection

1) Flush pipe per NFPA 24.

2) Disinfect each section of the new line in accordance with AWWA C651.

3) Final Flushing: Following chlorination, flush all treated water from the pipeline until the replacement water in the pipeline throughout
its length shows a residual of chlorine not in excess of that in the municipal source of water.

4) Bacteriological testing: Give the Resident Engineer 48 hours notice of a time for the University of Washington Environmental Health and Safety representative to come and collect water samples for bacteriological examination.

5) If bacteriological examination shows evidence of contamination, flush and re-sample, or re-disinfect, flush and re-sample until acceptable bacteriological sample results are obtained.

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 system, temporary bypasses, and utility support 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 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
   2. City of Seattle (COS):
      a. Standard Specifications for Road, Bridge, and Municipal Construction
      b. Standard Plans for Municipal Construction
   3. Washington Administrative Code (WAC)
      a. Chapter 296-155 WAC Safety Standards for Construction Work

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 specifications.

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 structural utility support systems, submit qualifications of design engineer demonstrating similar recent design experience.

E. Working Drawings: For any contractor designed structural utility support system or structural modifications to an existing structural utility support system, 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, Drawing N21-SZ001. 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 any structural utility support system designed by the Contractor or structural modifications to an existing structural utility support system, 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, connections and their elevations and depth of burial on the 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 structural 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, modify 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. Pipe, fittings, and joints: As indicated on the Contract Drawings.
   1. Reinforced Concrete Pipe: City of Seattle Standard Specifications Section 9-05.1.
   2. Polyvinyl Chloride (PVC) Pipe for gravity sewers: Pipe, fittings and joints in accordance with the City of Seattle Standard Specifications Section 9-05.3.
   3. Restrained Joint Ductile Iron Pipe and Fittings:
      a. Ductile Iron Pipe conforming to AWWA C151.
      b. Push-on joints conforming to AWWA C111.
      c. Cement mortar lined in accordance with AWWA C104.
      d. Thickness Class 50 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.

B. Precast Manholes, Appurtenances and Related: City of Seattle Standard Specifications Section 9-12.


PART 3 - EXECUTION

3.01 CONSTRUCTION

A. Pipe Trenching, Bedding, and backfilling is specified in Section 31 23 33, Trenching and Backfilling.

B. Pipe abandonment and removal is 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.

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. Pipe installation: COS Standard Specification Section 7-17.3(2).

F. The U220 contractor is required to install a structural utility support system for the 18-inch diameter sewer which crosses the station excavation. Maintain this structural utility support system and modify as needed to fully support the 18-inch sewer until such time that the sewer is bedded within the notch in the station roof structure.

G. Monitor structurally supported sewer for movement for the duration it is structurally supported. Notify Resident Engineer and implement remedial measures if movement exceeds the maximum allowable amount specified in Article 1.05.A, herein.

H. Temporary Sewer Bypass: If necessary to complete the work, 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. For work at the University of Washington, schedule work to avoid pumped bypasses when Husky Stadium is in use for football games or other similar largely attended events.

3.02 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.

2. The Resident Engineer will notify University of Washington Engineering staff as to the date and time of testing for work on or connecting to University owned sewers. A University representative must witness the tests and approve all testing before the sewer is placed into service.

B. Cleaning and Testing:

1. Clean pipes and manholes and perform testing as specified in the COS Standard Specification Section 7-17.3(4)B.

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 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)I. Submit two copies to the Resident Engineer within five days of recording. The Resident Engineer will provide one copy to the University of Washington within 10 days of recording.
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, including both perforated and solid, culverts, related drainage structures, trench drains, catch basins, drainage inlets, storm manholes, and the related 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 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.

1.03 DEFINITIONS

A. COS Standard Specifications: 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.

   1. Pipe
   2. Jointing
   3. Catch Basins and Manholes
   4. Frame, Grates and Solid Covers
5. Flexible Couplings

6. Manufacturer’s affidavit certifying compliance of materials with these Specifications.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe

1. Pipe used for storm drains as specified herein:
   a. Flexible Pipe Material:
      1) Polyvinyl Chloride (PVC): City of Seattle Standard Specifications Section 9-05.3
   b. Rigid Pipe Material:
      1) Concrete: City of Seattle Standard Specifications Section 9-05.1.
      2) Ductile Iron: City of Seattle Standard Specifications Section 9-05.2.

2. Meet the requirements of the City of Seattle Standard Specifications, 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 the same material as pipes and in accordance with the manufacturer’s recommendations. Meet the requirements of the City of Seattle Standard Specifications, Section 9-05.

C. Polyethylene encasement: Provide ductile iron pipe and fittings with 8-mil polyethylene encasement in accordance with the City of Seattle Standard Specifications, Section 9-30.1(6) D.

D. Catch Basins and Manholes: Use type as noted on the Contract Drawings in accordance with the City of Seattle Standard Plans.

E. Frame and Grate: Use cast iron in accordance with the City of Seattle Standard Plans.

F. Flexible Couplings: in accordance with AWWA C219. Coat center sleeve and end rings with fusion-bonded epoxy, and provide Type 304 stainless hardware. Provide Romac Style 400 or approved equal.

G. Trench Drains: ACO H100K as manufactured by ACO USA or approved equal.
PART 3 - EXECUTION

3.01 PREPARATION
A. Abandon existing storm drain systems as specified in Section 02 41 00, Demolition, in accordance with Section 2-02.3(5) of the City of Seattle Standard Specifications.

3.02 CONSTRUCTION
A. Follow the requirements of the COS Standard Specifications, Section 7-05, and Section 7-17 for the construction and installation requirements for the pipe, related structures, and other incidental work. Additional requirements for excavation trenching, and backfilling are specified in Section 31 23 33, Trenching and Backfilling.

B. Maintain uninterrupted service with temporary storm sewer bypass as depicted on the Contract Drawings and specified in Section 33 30 00, Sanitary Sewerage Utilities. The temporary storm sewer bypass shall be capable of bypassing the full pipe flow of 31,000 gpm. If the 5-day weather forecast for the duration of bypassing is for no precipitation, the bypass flow capacity may be reduced to one-half of the full flow or 15,500 gpm.

C. Remove and/or abandon existing Storm Drain System as depicted in the contract documents, in accordance with Section 02 41 00, Demolition.

3.03 FIELD QUALITY CONTROL
A. Clean and test pipelines and appurtenances within 15 working days after backfilling of pipelines and structures. Test all pipe, with the exception of restrained joint ductile iron pipe through steel casings, for leakage after installation in accordance with the City of Seattle Standard Specifications, Section 7-17.3(4). Pressure test restrained joint ductile iron pipe in steel casings in accordance with the City of Seattle Standard Specifications for Municipal Construction, Section 7-11.3(11)A1.

B. Videotape the interior of all storm pipes 6 inches through 48 inches to determine the acceptance of the Work. Follow the City of Seattle Standard Specifications, Section 7-17.3(4)I for the TV inspection work. Submit two copies of the records to the Resident Engineer.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for subsurface foundation drains at abutments, retaining walls, and building walls; permeable drainage panels; perforated pipe; and composite underdrains with piping, filter aggregate, and filter fabric 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 31 23 33, Trenching and Backfilling.

1.02 REFERENCES

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


2. City of Seattle (COS):
   b. COS Standard Specifications for Road, Bridge, and Municipal Construction.

1.03 DEFINITIONS

A. COS Standard Specifications: 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 COS Standard Specifications.

1. Pipe
2. Jointing
3. Flexible Couplings
4. Manufacturer’s affidavit certifying compliance of materials with specifications.

PART 2 - PRODUCTS

2.01 MATERIALS

A. Pipe and Fittings

1. Pipe Connection Requirements: To ensure continuous alignment of pipe, ends of pipe should be bell-and-spigot, grooved, ship lapped, or secured with couplings, collars, or other connection fittings.

2. Plastic Pipe:
   a. Pipe:
      1) Perforated PVC Pipe: Perforated polyvinyl chloride sub-surface drain (SSD) pipe and fittings shall be ASTM D 2241 SDR 21 (Class 200) with rubber gasket joints. Pipe shall have slotted perforations 0.040 inch wide by 1.0 inch long and spaced 0.25 inches apart on center. Pipe size shall not exceed 8-inch diameter unless indicated otherwise in the drawings.
      2) Solid Wall PVC Pipe: PVC pipe shall conform to the requirements of ASTM D 3034 for diameter sizes 4-inch through 15-inch, and of ASTM F 679 for diameter sizes 18-inch through 48-inch. The minimum pipe stiffness shall be 46 lb/in/in.

B. Drainage Materials

1. Drainage and Filter Aggregates: For aggregate drainage and filter material (permeable material) for filling trenches under, around, and over underdrains, behind foundation and retaining walls, and for pervious blankets use clean, coarse sand and gravel or crushed stone, that conforms to the following gradings:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percentage Passing Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 inch</td>
<td>100</td>
</tr>
<tr>
<td>3/4 inch</td>
<td>80-100</td>
</tr>
</tbody>
</table>

3. Preformed Permeable Drainage Liner: Prefabricated composite plastic drainage panels designed to provide hydrostatic relief for concrete foundation walls and retaining walls as indicated. Use panels of a button-pattern or other raised dimple feature which forms a drain core with flow channels at least 3/8 inch in thickness or clear depth, with geotextile filter fabric bonded to the raised pattern to prevent soil from entering the core channels and blocking the flow of water. Furnish drainage liner complete with installation accessories.

4. Drainage Matting: Use composite drainage matting for hydrostatic-relief drainage liner, consisting of a nylon or polypropylene core geomatrix of open, three-dimensional design, with a geotextile filter fabric bonded to the core to prevent soil from entering the core and blocking the flow of water. Ensure a minimum thickness or clear depth of 1/2 inch. Furnish drainage matting complete with installation accessories.

5. Impermeable Sheet Liner: Flexible membrane sheeting, polyvinyl chloride conforming to ASTM D1593 or ASTM D3083, or synthetic rubber conforming to ASTM D3253, minimum 10 mils thick.
   a. Adhesive: Synthetic rubber base cement, manufactured for use with polyvinyl chloride or synthetic rubber membrane material for cold application.
   b. Tape: Use pressure-sensitive neoprene or vinyl-chloride rubber adhesive tape for sealing of laps and joints as recommended by the manufacturer of the sheet liner material or a heavy-duty cloth masking tape, minimum 3 inches wide.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Pipe Installation

1. Excavate trenches for underdrain pipe as indicated. When not indicated, excavate to a width equal to the greater of 21 inches or the outside diameter of the pipe plus 12 inches and to a depth of 2 inches minimum below the grade established for the invert of the pipe. Coordinate with Section 31 20 00, Earth Moving, and Section 31 23 33, Trenching and Backfilling as applicable.

2. Lay impermeable sheet liner over prepared and compacted subgrade where indicated. Lap edges not less than 4 inches and ends not less than 6 inches, with all laps sealed continuously with adhesive and tape. Repair punctures and tears in liner sheets that occur during subsequent construction operations per the Manufacturer’s recommendations but not less than a 1-foot overlap in all directions.
3. Lay pipe to line and grade indicated. If pipe is of the bell-and-spigot type, lay bells in crosscuts cut in trench. Lay pipe with bell end uphill.

4. Fill space below the pipe invert with a layer of drainage aggregate as shown on the plans. Lay pipe upon this layer, perforations down. Join sections with sleeve couplings furnished by the pipe manufacturer or other appropriate method as determined by the pipe-ends configuration and approved by the Resident Engineer. Employ appropriate equipment to draw pipe sections together.

5. Do not use rocks, bricks, broken concrete, or asphalt to give intermediate support to pipes. Do not leave stones larger than 2 inches or other hard objects in contact with the pipes.

6. Fill excavations for underdrains with drainage or filter aggregates as shown in the plans. Place drainage aggregate and compact per COS Specifications, Section 7-01.3(2) to fill voids and prevent settlement, without damaging the underdrain pipe.

B. Composite Underdrains:

1. Construct composite underdrains as indicated in the plans. Surround perforated pipe with filter aggregates and envelope the composite underdrain with filter fabric as indicated in the plans. Provide solid-wall PVC pipe risers and cleanouts, including installation accessories, as indicated.

C. Installation of Permeable Drainage Liner

1. Apply preformed permeable drainage liner or drainage matting to below-grade concrete walls as indicated on the structural plans of the Contract Drawings. Apply panels in accordance with the manufacturer's instructions, with filter fabric side out.

2. Shingle each course, overlapping panels in the direction of water flow. Provide side laps in accordance with manufacturer's instructions.

3. Provide interface with subsurface drainage piping at footings where indicated on the plans. Follow manufacturer's instructions for correct interface installation.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY:
   A. This Section includes specification for installation of the precast concrete vaults and
      handholes as indicated 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 23 33, Trenching and Backfilling.

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
         a. ASTM C857 Standard Practice for Minimum Structural Design Loading
            for Underground Precast Concrete Utility Structures
         b. ASTM C858 Standard Specification for Underground Precast Concrete
            Utility Structures

1.03 SUBMITTALS
   A. Procedures: Section 01 33 00, Submittal Procedures.
      1. Shop Drawings for fabrication and installation of precast concrete structures and
         cast-in-place concrete structures showing:
         a. Concrete mix design for precast concrete structures.
         b. Reinforcing steel design for precast concrete structures including sizes,
            spacing, placement details, and other information to fully describe the
            reinforcing system.
         c. Cover and frame details for precast concrete structures.
      2. Complete materials list of manufactured items proposed under this Section
         showing:
         a. Manufacturers’ specifications and product data
         b. Demonstrated compliance with these Contract Specifications.
PART 2 - PRODUCTS

2.01 MATERIALS

A. Precast Concrete Handholes and Vaults

1. Manufacture precast concrete handholes and vaults in accordance with ASTM C858, Underground Precast Concrete Utility Structures.

2. Design Requirements

a. Conform to structural design requirements of ACI 318 for reinforced concrete capable of withstanding earth pressures, traffic, lifting and other appropriate loadings recommended in ASTM C857.

b. Design structures located partially or entirely within roadways for live loads of AASHTO HS20-44 Truck loadings plus impact.

c. Design bottoms of concrete structures to be watertight below grade, with preformed butyl rubber gaskets in joints between precast sections.

d. Provide concrete inserts for mounting cable supports, knockouts for conduits, frames, grates, covers, sumps, opening for ground rods, lifting eyes, and other features included with the standard handholes and vaults.

e. Provide risers and adjustment rings as required to position structure at depth to accommodate ductbanks, and keep clear of roadway structures.

3. Design Loads

a. Roof

1) Dead Load: Self weight plus soil cover


b. Walls

1) Surcharge Live Load

2) Unit Weight of soil: 120 pounds per cubic foot (pcf).

3) Coefficient of Active Earth Pressure (Ka) – 0.33.

4) Groundwater at ground surface with vault or handhole empty.

c. Base

1) Dead load plus hydrostatic uplift pressure acting on base.

2) Live load transmitted to base consisting of the maximum live load imposed on the roof.

d. Buoyancy
1) Ensure dead weight of structure is greater than 1.1 times the hydrostatic uplift force on the base of the vault or handhole.

B. Frames and Covers
1. Castings:
   a. Tough, closed-grain, ductile iron, smooth, clean and free of blisters.
   b. Plane or grind bearing surfaces to ensure flat, true surfaces within ring and cover at all points.
   c. Use vented covers that have grate spacing at 5/8-inch maximum.
2. Identification
   a. Cast, imprinted, or welded bead identifying the assigned utility company:
      1) On concrete collars surrounding castings and hatches.
      2) Submit identification marking plan including type of marking and size for acceptance.

C. Power Vault Type 687-LA: Utility Vault Model 687-LA, or approved equal with round access opening, frame and nonskid cover in accordance with Seattle City Light Standards. Include riser sections as required.

D. Handhole; Utility type handhole; dimensions as shown on Contract Documents.

E. Ground Rods:
   1. 5/8-inch diameter copper-clad steel ground rods, 10-foot long.

F. Vault Sumps
   1. Provide galvanized cover gratings on all vault trench sumps.

G. Pulling Irons
   1. Vaults and Handholes Type 444 and larger: With pulling irons.
   2. Vaults Type 712 and larger: With pulling irons rated at 40,000 pounds breaking strength.
   3. Provide test result reports for typical vault application.

PART 3 - EXECUTION

3.01 CONSTRUCTION

A. General
   1. Provide Seattle City Light 4 weeks notice prior to the date requested to connect to the existing Seattle City Light Vault. Do not enter or connect to existing Seattle City Light facilities without pre-approval and onsite supervision of Seattle City Light workers.
2. Field cutting will not be allowed without approval. Block out all openings before casting or core drilling.

3. Field cutting for handhole and vault slots for installation of vaults and handholes over existing communications buried wire and cables may be approved on a case by case basis by the Resident Engineer. The Resident Engineer may approve slot location and construction method before cutting. Do not penetrate structural ribs in vault during field cutting openings.

4. Handling and Erection Stress: Provide additional reinforcing inserts and other features required to ensure vaults remain undamaged during handling and installation.

B. Excavation, Trenching and Backfill:

1. Conform to Section 31 23 33, Trenching and Backfilling.

2. Provide bedding for the precast concrete structures consisting of 4 inches of crushed rock (1-1/4 inch minus) topped with 1/2 inch to 1-1/2 inches of sand.

3. Place granular backfill in compacted lifts around all sides of handholes and vaults.

C. Precast Sections

1. Carefully align and seat precast vault and handhole sections against the butyl rubber gasket to ensure a watertight perimeter seal for all joints.

2. Remove lifting lugs or inserts, wet the recessed surfaces, fill with mortar mixed with polyvinyl acetate, and finish to a smooth surface prior to backfilling.

3. Seal conduit penetrations watertight after installation.

4. Completed precast vaults and handholes to be straight, plumb, aligned, and at correct finish elevation. Match frames and covers to finish grade and slope of sidewalk, planting strip, roadway and other finish surfaces.

D. Ground Rods

1. Install two grounding rods in all concrete vaults. Install ground rods in opposite corners of vaults.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY

A. This Section includes specifications for furnishing, installing and/or modifying traffic signal heads, controller cabinets, conduit, conductors, loop detectors, junction boxes, and appurtenances, 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

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


1.03 SUBMITTALS

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

B. Submit manufacturer’s product data for all signal equipment to the Resident Engineer for acceptance.

C. Traffic Control Plan. Plan will be in accordance and part of Section 01 55 26, Traffic Control.

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, use materials and perform work to conform to the applicable requirements of the jurisdictional agency’s standard drawings and specifications.

   a. All traffic signal materials will conform to COS standards and specifications.
PART 3 - EXECUTION

3.01 CONSTRUCTION

A. For traffic signals on streets, roadways and parking areas that are to be owned or maintained by COS, perform the work described in this Section in accordance with the applicable requirements of the COS standard drawings and specifications.

B. Design, materials used and installation of the blank out signs will be coordinated and approved by COS.

END OF SECTION
PART 1 - GENERAL

1.01 SUMMARY
A. This Section includes specifications for fabricating and installing multi-rotational, high load disk bearing assemblies for the pedestrian bridge. Assemblies include bearing device, distribution plates, distribution pads, and connection hardware.
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 05 05 23, Metal Fastenings

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):
      b. LRFD Bridge Construction Specification, 4th Edition
      a. ASTM A240 Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
      b. ASTM A709 Standard Specification for Structural Steel for Bridges

1.03 SUBMITTALS
A. Procedures: Section 01 33 00, Submittal Procedures.
B. Shop Drawings: Submit bearing shop drawings including the following:
   1. Plan and elevation of each disk bearing size.
   2. Details and sections with material specifications.
   3. Vertical and horizontal load capacities.
   4. Bearing seat and bearing connection details and locations.
C. Qualifications: Submit qualifications for the following demonstrating conformance:
   1. Manufacturer
2. Professional Engineer

D. Certifications: Submit material certifications for the following demonstrating conformance:

1. Carbon Steel
2. Stainless Steel
3. PTFE
4. Polyether Urethane

E. Source Quality Control Test Reports
F. Field Quality Control Test Reports

1.04 QUALITY ASSURANCE

A. Manufacturer:
   1. A minimum of five years experience in the design and fabrication of disk bearings
   2. A minimum of ten successful bridge bearing design and fabrication projects.

B. Professional Engineer: Licensed structural engineer currently registered in the State of Washington, with a minimum of five years experience in disk bearing design.

1.05 DELIVERY STORAGE AND HANDLING

A. Store and handle bearing assemblies in conformance with manufacturer’s written directions.

B. Handle bearing assemblies by the bottom surface only. Do not lift or move bearings by the top, side, or shipping bands.

C. Do not disassemble bearing assemblies in the field unless authorized to do so by the Resident Engineer.

PART 2 - PRODUCTS

2.01 MANUFACTURERS

A. R. J. Watson, Inc., Amherst, NY, or approved equal

2.02 EXISTING PRODUCTS

2.03 MATERIALS

A. General: All materials shall be new and unused, with no reclaimed material incorporated into the finished bearing.

B. Carbon Steel: ASTM A709, Grade 50

C. Stainless Steel: ASTM A240 Type 304

D. Polyether Urethane Elements: AASHTO LRFD Bridge Construction Specification

E. Polytetrafluoroethylene (PTFE) Sheet: AASHTO LRFD Bridge Construction Specifications
1. Manufactured from pure virgin (not reprocessed) PTFE resin.
2. Resistant to all acids, alkalis, and petroleum products.
3. Stable at temperatures from -360 degrees Fahrenheit to +500 degrees Fahrenheit.
5. Minimum thickness: 0.188 inches.

F. Welded Headed Studs: Section 03 15 25, Anchorage to Concrete
G. Welding Electrode: Section 05 05 23, Metal Fastenings

2.04 MANUFACTURED UNITS
A. Disk Bearings
   1. Consist of a polyether urethane structural element (disk) confined by upper and lower steel bearing plates.
   2. Equipped with a shear-resisting mechanism and/or positive location device to prevent lateral movement of the disk.
   3. Supply as fixed bearings, guided expansion bearings, and non-guided expansion bearings as noted on the Contract Documents.
B. Pot bearings will not be permitted.

2.05 DESIGN
A. Design bearings in conformance with AASHTO LRFD Bridge Design Specification.
B. Provide for thermal expansion and contraction, rotation, camber changes, and creep and shrinkage of structural members.
C. Design sliding bearings to show negligible shear displacements within the vertical load support element.
D. Design vertical load support element (elastomer disk) for rotational fatigue at the design vertical load.
E. Rotational load is static dead load rotation plus cyclic live load rotation.
F. Unless otherwise noted, design for a minimum of 5 million cyclic rotations.
G. If bearings rely on lateral confinement of the elastomer to sustain the vertical load, include one-half the horizontal load in design.

2.06 FABRICATION
A. General
   1. Fabricate bearings in conformance with AASHTO LRFD Bridge Construction Specification
B. Stainless Steel
   1. Provide a minimum stainless steel thickness 0.063 inches.
2. Fasten stainless steel sheet to steel substrate with a continuous seal weld.

3. Polish stainless steel in contact with PTFE sheet to a bright mirror finish.

C. Fabrication tolerances:
   1. Out-of-flatness
      a. All bearing surfaces of steel plates: 0.010 inches per foot
      b. Bottom surfaces of masonry plates: 0.0625 inches per foot
   2. Surface roughness:
      a. Oxygen-cut surfaces: 1000 micro-inches RMS
      b. Stainless steel in contact with PTFE: 20 micro-inches RMS
   3. Gross bearing dimensions: 0 inch, + 1/8 inch

D. Mold elastomeric rotational element as a single piece; separate layers will not be allowed.

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

2.07 FINISHES

A. Shop coat all steel surfaces except stainless steel surfaces and steel surfaces to be field welded.

B. Prior to coating, clean all shop coat surfaces in conformance with coating manufacturer’s written directions.

C. Coat surfaces to be field welded with a coat of clear lacquer.

2.08 PACKAGING

A. After assembly including sole plates and masonry plate, hold bearing components together with steel strapping or other means to prevent disassembly until installation.

B. Package to prevent damage from impact, dust, and moisture contamination during shipping and storage.

2.09 SOURCE QUALITY CONTROL

A. Sampling and Testing:
   1. Perform production bearing sampling and testing in conformance with AASHTO LRFD Bridge Construction Specification.
   2. Visually examine each bearing before and after testing. Defects such as bond failure, physical destruction or cold flow of PTFE to the point of debonding, extruded or deformed elastomer or cracked steel shall be cause for rejection.

B. Identification: Indelibly mark each bearing with the project identification number, lot number, and individual bearing number on a side that will be visible after installation.

C. Testing
1. In lieu of long-term testing, perform accelerated rotational fatigue life testing with 15,000 complete cycles at ± 0.02 radians on a minimum of three full sized bearings.

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

E. Shop Welding Inspection and Testing: Section 05 05 23, Metal Fastenings

F. Shop Inspection and Testing by Resident Engineer: Notify the Resident Engineer 30 days prior to the start of bearing fabrication. Allow the Resident Engineer access to perform independent verification inspection and testing.

PART 3 - EXECUTION

3.01 INSTALLATION

A. Install bearings in conformance with manufacturer’s written directions and the approved Shop Drawings.

B. Install bearings level and parallel to within ± 0.005 radians.

3.02 FIELD QUALITY CONTROL

A. Field Welding Procedures and Personnel: Section 05 05 23, Metal Fastenings

B. Field Welding Inspection and Testing: Section 05 05 23, Metal Fastenings

C. Field Inspection and Testing by Resident Engineer: The Resident Engineer and the manufacturer’s representative will inspect the installed bearing components. Notify the Resident Engineer 30 days prior to the start of bearing installation. Allow the Resident Engineer access to perform independent verification inspection and testing.

3.03 ADJUSTING

A. Correct any elements out of tolerance as directed by the Resident Engineer.

3.04 PROTECTION

A. Protect polyether urethane materials from flame and spark.

B. Do not allow steel temperatures adjacent to polyether urethane materials to exceed 225 degrees Fahrenheit.

END OF SECTION
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University Link Light Rail
Link Contract U250

Geotechnical Conditions Summary
UW Station Finishes

May 2009

Prepared by:
Northlink Transit Partners
411 S. Jackson Street
Seattle, WA 98104
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UL Boring Laboratory Test Results
NB Boring Laboratory Test Results
Appendix A
Geotechnical Conditions Summary
UW Station Finishes

This document summarizes soil and groundwater conditions underlying the West Entrance and Pedestrian bridge at the University of Washington Station (UWS) and presents an evaluation of some of the difficulties to be expected during construction of the foundation elements. This document presents factual data from the borings, which may be relied upon for the development of construction cost estimates and for the evaluation of potential claims. This document is intended to inform contractors of potential difficulties with construction of foundation elements, thereby allowing the bidding contractors to select appropriate construction methods to successfully price and complete the prescribed work. This document is not intended to be a Geotechnical Baseline Report nor is it intended to dictate construction means and methods.

A.1 Surface Conditions

In the area of the West Entrance, the site is currently occupied as parking; however, prior to the U250 Contract award, the U220 Contractor will have completed site grading for construction, installed a soldier pile and lagging wall around the perimeter of the site, installed slurry walls for the Crossover Box and Station Box, and excavated and braced the Crossover Box. The U220 Contractor will excavate the site to elevation 53 feet prior to installation of the slurry walls for the Crossover and Station Boxes.

The pedestrian bridge cross Montlake Boulevard NE and NE Pacific Place. In the area of the crossing there are four traffic lanes in Montlake Boulevard and up to three traffic lanes in Pacific Place. Both are covered with asphalt. There are numerous overhead and underground utilities.

A.2 Subsurface Conditions

Our interpretation of subsurface conditions was based on the borings included in this Appendix.

A.2.1 Pedestrian Bridge

Borings UL-550, UL-555, UL-556, UL-557, UL-560, and UL-561 were drilled at the locations shown on the Site and Exploration Plan (Figure 1). The subsurface conditions are shown on the Pedestrian Bridge Subsurface Profile (Figure 5).

Soils

The pedestrian bridge alignment is underlain by fill, over Vashon glacial till and meltout till, over Pre-Vashon glacial outwash deposits.

Fill (Af) – Artificial fill was interpreted to be present along most of the pedestrian bridge alignment and predominantly consisted of loose to dense, silty sand with gravel. Due to the nature of these deposits, a wide range of material gradations and density/consistency should be anticipated including soft to medium stiff silt and clay. These soils are typically unsaturated, although local perching of groundwater may
occur atop the underlying glacial till. The fill thickness at the proposed pier locations is estimated to vary from 1 to 10 feet.

Vashon Glacial Till and Meltout Till (Qvt, Qvtm) – Glacial till and till-like deposits vary in thickness from about 30 to 40 feet. Glacial till is composed of a poorly-sorted mixture of silt, sand, gravel, cobbles, and occasional boulders (SM, GM). The meltout till generally consists of poorly-sorted and poorly-stratified, sandy silt deposits with interbeds of clean to silty sand and gravel (SP, SP-SM, SM, GP, GP-GM, GM). The till and meltout till have been glacially overridden and are typically dense to very dense or very stiff to hard. Glacial till and till-like deposits generally form aquitards with vertical permeabilities of about $5 \times 10^{-8} \text{ cm/sec}$ to $5 \times 10^{-6} \text{ cm/sec}$, upon which perched groundwater can accumulate. These units can contain isolated discontinuous beds or lenses of higher permeability, silty to clean, sand and gravel.

Pre-Vashon Glacial Outwash (Qpgf) – Glacial Outwash consists of dense to very dense, clean to silty sand, gravelly sand, and sandy gravel (SP, SP-SM, SM, GP, GP-GM, GM). Lenses and layers of silt and sandy silt (ML) are present within this sedimentary deposit. Borings UL-555 and UL-556 were terminated in this deposit at depths of 80 feet and 50 feet, respectively. The bottom of the outwash deposit was encountered at a depth of 118 feet in boring UL-561. Where saturated, it is generally an aquifer that is capable of transmitting large volumes of groundwater. However, low permeability lenses and interbeds of till-like deposits, as well as silt and sandy silt, are present within it and may act as discontinuous aquitards.

**Groundwater**

Groundwater levels were measured in piezometers at borings UL-556 near the west end of the bridge and UL-560 near the east end of the bridge. The groundwater level was measured at about elevation 36, which corresponds to depths ranging from 30 to 40 feet at the bridge pier locations. Locally perched groundwater may be encountered on the glacial till surface. Groundwater levels are expected to vary seasonally due to precipitation levels and regulated changes in the level of Lake Washington and the Lake Washington Ship Canal. Annual groundwater level fluctuations are on the order of 2 feet.

**A.2.2 West Entrance**

Borings UL-549 and UL-559 were drilled at the locations shown on Figure 2. The subsurface conditions are shown on the “Subsurface Profile – West Entrance” (Figure 4).

**Soils**

The west entrance area is underlain by fill (Af) over Vashon glacial meltout till (Qvtm) above Pre-Vashon glacio-fluvial or glacial outwash soil (Qpgf) units as described above for the pedestrian bridge subsurface conditions. In general the very dense, silty sand with gravel (SM) unit (Qvtm) thickens to the north from about 18 feet at UL-559 to 38 feet at UL-549 as the surface of the underlying more permeable, slightly silty sand (SP-SM) and slightly silty gravel (GP-GM) unit (Qpgf) dips down to the north. Lower permeability sandy silts, silts and clays were encountered below about elevation 22 feet at boring UL-559 and elevation 10 feet at UL-549.
Groundwater

Groundwater levels were measured in piezometers at boring UL-549. The design groundwater level is elevation 36 feet. Locally perched groundwater may be encountered on the glacial till surface above elevation 57 feet.

A.3 Dewatering

The local groundwater elevation is above the bottom of the excavations. In the northern half of the excavation, sumps will likely be sufficient to control the groundwater. A dewatering system consisting of vacuum wells, deep wells, or similar system will likely be required to control groundwater in the area of the sump pit. Seepage on the order of 15 gpm in the sumps should be expected, and up to 90 gpm in a dewatering system.

A.4 Drilled Shaft Construction

The glacial till and meltout till are very dense and may be difficult to excavate. In addition, boulders may be encountered in these units. Cobbles and boulders will slow the progress of drilled shaft installation. The use of a core barrel or a chisel may be required to advance through boulders, which could have unconfined compressive strengths up to 42,000 psi.

Saturated soil conditions will be encountered below the groundwater level at elevation 36 feet at the pier locations. If drilling depths extend below the groundwater table and into the Pre-Vashon glacial outwash sand (Qpgo), then flowing unstable ground conditions could occur.

A.5 Temporary Shoring

Temporary shoring will be required to support the West Entrance excavation. Lateral earth and surcharge pressures for design are presented in the plans.

A.6 Obstructions

Although not encountered in the site explorations, obstructions may be encountered during excavation. Drilled shafts may encounter obstructions, such as concrete rubble, brick, timber, and organics (including logs) within the artificial fill. Similar materials may also be encountered in the artificial fill within the Station Box and West Entrance excavations.

Boulders will likely be encountered while excavating the Station Box and West Entrance; most likely on the contact between the Qpgf/Qpgd and the Qpgl. The quantity and sizes of boulders that may be encountered are summarized in the table below. The unconfined compressive strengths of the boulders will range up to 42,000 psi.
A.7 Soil Disposal

The natural pH of the soil varies from 5.5 to 9.8; 20% of the soil excavated from the West Entrance and the Station Box will have a pH greater than 8.5; while 5% of the soil excavated from the West Entrance and the Station Box will have a pH less than 6.5.

Hazardous or contaminated materials were not encountered in the test borings at the UWS site, and are not expected in the excavations for the Station Box and West Entrance.
The image contains a geological classification system chart and a borehole log legend. The chart lists soil classifications under different major divisions: Clean Gravel, Well-Graded Gravel, Poorly Graded Gravel, Gravelly Gravel, Silty Gravel, Clayey Gravel, Clean Sands, Well-Graded Sands, Poorly Graded Sands, Silty Sands, Clayey Sands, Silt & Clay (Liquid限) Inorganic, CL, Low Plasticity Organic Clay, OR, High Plasticity Organic Clay, OR. The borehole log legend includes symbols for final design boring, preliminary engineering boring, top of rail elevation, ground surface elevation, alignment station, and more. The document is related to the University of Washington Station finish and pedestrian bridge plan and profile legend.
Boring Logs
Hole excavated with an air knife and hand auger to 7', no samples.

Moist, silty SAND (SM); (Af).

Dense, moist, gray-brown, gravelly, silty SAND (SM); fine to coarse, sub-rounded gravel, thin lens of SILT, occasional organics at 7' (Qvt).

Trace iron oxide staining, fine to medium sand, diamictic texture.

Grades to gray.

Dense, moist, gray-brown, slightly silty, gravelly, fine SAND (SP-SM); interbedded with slightly silty, gravelly SAND (SW-SM); and gravelly, silty, fine SAND (SM); trace medium to coarse sand (Qvtm).

Dense, moist, gray-brown, gravelly, silty SAND (SM); fine to coarse gravel, fine to coarse sand, diamictic texture (Qvtm).

Dense, moist, gray-brown, gravelly SAND (SW); trace silt, fine to coarse sub-rounded gravel, fine to coarse sand (Qvtm).

Pockets of silty, fine to medium poorly graded SAND.
Hard, moist, gray-brown SILT (ML); trace clay, trace fine sand, dark brown organic silt with pockets of gravelly, silty, fine to medium sand (Qpnl).

Gray, moist, slightly gravelly silty SAND (SM); fine to medium sand (Qpfn).

Dense, moist, gray, gravelly, silty SAND (SM); fine to coarse gravel, fine to coarse sand, trace iron oxide staining, diamictic (Qpgt).

Hard, moist, gray, silty CLAY (CL-CH); trace fine sand, gravel, with lenses and thin laminations of clayey SILT, medium to high plasticity (Qpgl).

Hard, moist, gray clayey SILT (MH) and interbedded silty CLAY (CL/CH); medium to high plasticity (Qpgl).

Gravelly, clayey, silty SAND (SM); (Qpgd).

Hard, moist, gray clayey SILT (MH) and interbedded silty CLAY (CL/CH); medium to high plasticity (Qpgl).

PP > 4.5 tsf

Sample lost, 60' to 64'

MC, AL, CT
### Log of Boring UL-545

**Project:** Sound Transit / University Link Light Rail  
**Project Location:** Seattle Washington  
**Contract Number:** RTA/LR 8-06

#### ELEVATION (ft)  
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#### MATERIAL DESCRIPTION
- **Scattered slickensides.**
- **Occasional slickensides.**

#### REMARKS AND TESTS
- **SAT, XRD**  
  - PP > 4.5 tsf  
- **MC, AL**  
- **CL/CH**  
  - Occasional slickensides.
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<th>RETAINED INTERVAL</th>
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<td>Occasional gravel dropstones.</td>
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Terminated boring at 130 feet below ground surface.

PP = 3.5 tsf
**Log of Boring UL-546**

Date(s) Drilled: 6/26/2007 - 6/30/2007

**Geotechnical Consultant:** NORTHLINK TRANSIT PARTNERS

Logged By: S. Johnston

Checked By: ZN/TDC/HHH/DHM

**Total Depth of Borehole:** 131.5 ft

**Drilling Method/Rig Type:** Mud Rotary / Truck Mounted

**Hammer Weight/Drop (lb/in.):** Automatic 140 lbs / 30-in

**Ground Surface Elevation/Datum:** 59.7 ft / NAVD 88

**Coordinates:** N 540156  E 1578062

**Core Diameter:** 6 in

**Elevation Source:** SURVEY

**Date(s) Drilled:** 6/26/2007 - 6/30/2007

**Location:** STA. 1203+58  /  -10 ft

**Coordinates:** N 540156  E 1578062

**Elevation Source:** SURVEY

**Material Description:**
- Fill (Af).
- Very dense, slightly moist, gray-brown, silty, sandy GRAVEL (GM); trace clay (Qvt).
- Very dense, moist, gray-brown, silty, gravelly SAND (SM) (Qvt).
- Slightly gravelly, fine to medium sand, trace coarse sand.

**Remarks and Tests:**
- 0-8’ vacuum drilled - no sample recovered
- Pressure meter test
- Hammer test
- SA
- Hammer test

**USCS:**

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<td>Very dense, slightly moist, gray-brown, silty, sandy GRAVEL (GM); trace clay (Qvt).</td>
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<tr>
<td>SM</td>
<td>Very dense, moist, gray-brown, silty, gravelly SAND (SM) (Qvt).</td>
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<tr>
<td></td>
<td>Slightly gravelly, fine to medium sand, trace coarse sand.</td>
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**Piezometer Schematic:**

**Groundwater Level:**

**Graph:**

**Log of Boring UL-546**

**Sheet 1 OF 4**

**Project:** Sound Transit / University Link Light Rail

**Project Location:** Seattle Washington

**Contract Number:** RTA/LR 8-06
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<td>SPT 4</td>
<td>28-50/4</td>
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<td>SM</td>
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<td>Very dense, moist, gray, SILT (ML); trace fine sand and clay, slow to rapid dilatancy (Qpgl).</td>
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<td>55</td>
<td>SPT 5</td>
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<td>100</td>
<td>ML</td>
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<td>Hard, moist, gray, silt CLAY (CL/CH); trace to slightly sandy, trace fine gravel dropstones, medium to high plasticity (Qpgl).</td>
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<tr>
<td>65</td>
<td>SPT 6</td>
<td>7-17-26</td>
<td>100</td>
<td>CL/CH</td>
<td></td>
<td></td>
<td>Trace fine sand.</td>
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</table>

**Remarks and Tests**

- Hammer test
- MC, AL, CT
- Hammer test
- PP > 4.5 tsf
- Hammer test
- MC, AL, CT
- Hammer test
Few slickensides at high angles (~65°).

Generally massive texture.

Fine subrounded gravel dropstone.
### Log of Boring UL-546

**Project:** Sound Transit / University Link Light Rail  
**Project Location:** Seattle Washington  
**Contract Number:** RTA/LR 8-06

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<td>SPT 11</td>
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<td>Generally massive texture.</td>
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<td>Hammer test</td>
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<td>SPT 12</td>
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<td>SPT 13</td>
<td>6-16-21 (37)</td>
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**Terminated boring at 131.5 feet below ground surface.**
Hole was hand excavated using forced air and a hand auger to 8'. No samples were taken.

Medium beds of silty fine SAND and clean fine SAND.

Dense, moist, gray-brown, gravelly, very silty, fine to medium SAND (SM); trace coarse sand, paleosol at 30' (Qpgtm).

Pressure meter test from 25 to 31' SA
Dense, moist, gray-brown, slightly silty, fine SAND (SP-SM) (Qpgf).

Dense, moist to very moist, gray, fine sandy SILT (ML); trace fine gravel dropstones, slow to rapid dilatancy (Qpgl).

Hard, moist, gray, slightly gravelly, slightly sandy, clayey SILT (MH)/silty CLAY (CL); fine gravel dropstones, medium to coarse, angular sand, medium plasticity, medium dilatancy (Qpgd).

Becomes very stiff, with thin beds of SILT (ML); trace clay and thin laminations of fine to medium SAND.

Medium to dense, moist, gray, slightly gravelly, clayey, silty SAND (SM); fine to coarse gravel, fine to coarse sand, with pieces of clay mixed in, disturbed texture (Qpgd).

Hard, moist, gray, silty CLAY (CH); interbedded with thin lenses of clayey silt, medium to high plasticity, disturbed texture (Qpgl).
Dense, moist, gray, slightly gravelly, silty SAND (SM); fine to coarse gravel, sub-rounded to angular, diamictic structure, with intermittent pockets of coarse sand and occasional pieces of clay (Qpgtm).

Hard, moist, gray, gravelly, sandy, silty CLAY (CL); with thin laminations of fine to medium sand (Qpgd).

Medium stiff to stiff, moist, gray, silty CLAY (CL-CH); trace sand, trace gravel, with interbeds of clayey silt, medium to high plasticity, disturbed texture (Qpgl).

Hard, moist, gray slightly sandy, silty CLAY (CL); trace gravel (Qpgl).

Hard, moist, gray, silty CLAY (CH); interbedded with clayey SILT (MH); disturbed to brecciated texture, medium to high plasticity, massive (Qpgl).
Scattered round, fine gravel dropstones to 150'.

Hard, moist, gray slightly clayey to clayey SILT (MH); (Qpgl).
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<th>TYPE/NUMBER</th>
<th>RETAINED INTERVAL</th>
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<td>Hard, moist, gray silty CLAY (CH); high plasticity (Qpgl).</td>
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<td></td>
<td>100</td>
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Terminated boring at 160 feet below ground surface.
No samples were taken, boring was for well install only.
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</tbody>
</table>

Terminated boring at 45 feet below ground surface.
Hole was hand excavated to 10.5’ with forced air and a hand auger. No samples were taken.

Medium dense to loose, very moist, gravelly, silty SAND (SM); trace clay, iron oxide stained (Af).

Dense, moist, gray-brown, gravelly, silty SAND (SM); fine to coarse, sub-angular to sub-rounded gravel, fine to medium sand, diamicitic texture (Qvt).

Dense, moist, gray-brown, gravelly, fine to medium SAND (SP) (Qvtm).

Dense, moist, gray-brown, slightly gravelly, silty fine and fine to medium SAND (SM) (Qvtm).

Dense, moist, gray-brown, slightly silty, fine to medium SAND (SP-SM); trace gravel (Qvtm).
Moist to wet, brown-gray, sandy SILT (ML); trace organics, fine to medium sand, rapid dilatancy (Qpnl).

Dense, moist, gray-brown, gravelly SAND (SW); fine to coarse sand, clean to trace silt, sub-angular gravel with interbeds of dense, till-like silty SAND (SM) (Qpgf).

Dense, moist, gray-brown to gray, silty SAND (SM); fine sand (Qpgf).

Dense, moist to very moist, brownish-gray SILT (ML); trace clay, thinly laminated with thin interbeds of fine to coarse sand and silty-fine sand, low plasticity (Qpgl).

Dense, moist, gray, gravelly, sandy SILT (ML); trace clay, diamict structure, disturbed texture (Qpgd).

Very dense, moist to wet, gray, fine sandy SILT (ML); trace fine, round gravel, with interbeds of silty fine SAND, occasional organics, rapid dilatancy (Qpgl).
Hard, moist, gray silty CLAY (CL); with pockets of clayey SILT, occasional fine organics, laminated, disturbed texture, medium plasticity (Qpgl).

Becomes interbedded with thin lenses of slightly gravelly CLAY, trace sand, fine to coarse, angular gravel.

Gravely, silty, sandy, fine angular gravel, diamictic structure.

Pocket of medium sand.

Becomes interbedded with a gravelly, sandy, silty, diamictic clay, fine, angular gravel from 87' to 102'.
Scattered fine to coarse gravel dropstones.

Hard, moist, gray, silty CLAY (CL); interbedded with clayey SILT and SILT (MH); slow dilatancy (Qpgl).
Terminated boring at 160 feet below ground surface.

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>DEPTH</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>GRAPHIC LOG</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
<th>REMARKS AND TESTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>-90</td>
<td></td>
<td></td>
<td>CL/MH</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>160</td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Drill action and mud return suggests sand and gravel.

Moist, gray-brown, slightly silty to silty, gravelly SAND (SM); fine sand, fine to coarse subrounded to subangular gravel (Qvtm).

Occasional organics from 30’ to 33.5’.

Silty zone from 32’ to 32.5’.

Medium dense to dense, moist, gray-brown, silty, gravelly SAND (SM); fine to medium sand, fine to coarse subangular to rounded gravel (Qtsm).

0-8’ vacuum drilled - no sample collected

8-15’ mud rotary

15-21’ pressure meter test

21-25’ mud rotary
subrounded gravel, till-like, 3" gravel lens at 33.5' (Qvtm).

Dense, moist, gray-brown, Silt (ML); trace clay, trace gravel, interbedded with silty Sand (SM); fine to medium sand, trace gravel (Qpnl).

Dense, moist, gray-brown, slightly silty, sandy gravel (GM); fine to medium sand, fine subrounded gravel, occasional organics (Qpgf).

Laminations of silt-clayey silt.

Dense, very moist, gray, silty Sand/sandy Silt (SM/ML); fine sand (Qpgf).

Gray, fine sand (SP); trace silt.

Dense, very moist, gray, fine sandy Silt (ML) (Qpgf).

Very dense, very moist, gray, silty Sand (SM) and sandy Silt (ML); fine sand, occasional thin lamination (Qpgf).

Luminescence age date: 60,530 to 92,040 ybp.

55-61' pressure meter test
Zones of silty clay within the silty SAND from 75' to 78'.

Dense, very moist, gray, silty SAND (SM); fine sand (Qpgf).

Hard, moist, gray, clayey SILT (MH); trace sand, trace fine subrounded gravel, many dropstones, disturbed texture (Qpgd).

Hard, moist, gray, slightly silty CLAY (CH); high plasticity, disturbed texture (Qpgl).

Dense, moist, gray, gravelly, silty, clayey SAND (SC); diamict, disturbed texture (Qpgd).

Dense, moist, gray, sandy SILT (ML); fine sand (Qpgl).

Loose, very moist to wet, gray, silty SAND (SM); fine to medium sand (Qpgf). Interbeds of silty fine sand, silt, and clayey silt from 95' to 98'.

Becomes wet at 98'.

Hard, moist, gray, slightly silty CLAY (CH); high plasticity, highly disturbed texture (Qpgl).

Scattered dropstones from 106' to 110'.

Brecciated texture, abundant slickensides.
Lens of clayey Silt, less disturbed.

Coarse gravel dropstone.

Hard, moist, gray, clayey Silt (MH) (Qpgl).

Hard, moist, gray, silty Clay (CH); disturbed texture (Qpgl).

Minor high angle slickenside fractures from 124' to 125', small fine sand inclusion at 125'.

Minor high angle fracturing and a few rotated clay fragments from 139' to 140', interbedded with clayey Silt (MH) from 140' to 143'.

Massive texture.

Wood fragment.

Coarse gravel dropstone, joint at 45°.
#### Log of Boring UL-549

**Table:**

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>GRAPHIC LOG</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
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<tbody>
<tr>
<td>-90</td>
<td></td>
<td>CC 25c</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Interbeds of clayey SILT.</td>
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<tr>
<td>-95</td>
<td></td>
<td>ST 26</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>-100</td>
<td></td>
<td>ST 27a</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>Occasional very fine organic fragments.</td>
</tr>
<tr>
<td>-100</td>
<td></td>
<td>ST 27b</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-100</td>
<td></td>
<td>ST 27c</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
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<tr>
<td>-100</td>
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<td>CC 28</td>
<td></td>
<td>50</td>
<td></td>
<td>CH</td>
<td></td>
</tr>
<tr>
<td>-105</td>
<td></td>
<td>ST 29a</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>Scattered thin laminations.</td>
</tr>
<tr>
<td>-105</td>
<td></td>
<td>ST 29b</td>
<td></td>
<td>100</td>
<td></td>
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</tr>
<tr>
<td>-105</td>
<td></td>
<td>ST 29c</td>
<td></td>
<td>100</td>
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<tr>
<td>-110</td>
<td></td>
<td>CC 30</td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>Scattered fine gravel dropstones, disturbed texture, slickensides.</td>
</tr>
<tr>
<td>-115</td>
<td></td>
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<td>-170</td>
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<tr>
<td>-180</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Terminated boring at 180 feet below ground surface.</td>
</tr>
</tbody>
</table>
Hole was hand excavated with forced air and hand auger to 7.5'.

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>5</td>
<td>CC 1</td>
<td>100</td>
<td>Asphalt parking lot.</td>
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<tr>
<td>60</td>
<td>10</td>
<td>CC 2</td>
<td>100</td>
<td>Medium dense, moist,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>silty SAND (SM); (Af).</td>
</tr>
<tr>
<td>55</td>
<td>15</td>
<td>CC 3</td>
<td>100</td>
<td>Dense, slightly moist,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>brownish-gray, gravelly,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>silty SAND (SM); fine</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>to medium sand, fine to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>coarse, sub-rounded to</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>angular gravel,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>diamicctic structure,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>with thin interbeds of</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>sand (Qvtm).</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
<td>CC 4</td>
<td>100</td>
<td>Medium bed of moist,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>thinly laminated,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>silty fine sand.</td>
</tr>
</tbody>
</table>

Note: The material description indicates the geotechnical properties of the soil encountered during drilling.
<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
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<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>CC 5</td>
<td></td>
<td></td>
<td>100</td>
<td>Very moist, brownish-gray, slightly gravelly, fine to medium SAND (SP); trace silt and coarse sand sub-rounded gravel, intermittent beds of fine to medium, medium to coarse, and fine to coarse sand (Qpgf).</td>
</tr>
<tr>
<td>40</td>
<td>CC 6</td>
<td></td>
<td></td>
<td>100</td>
<td>Medium bed of slightly silty, gravelly, fine to coarse SAND (SW-SM).</td>
</tr>
<tr>
<td>45</td>
<td>CC 7</td>
<td></td>
<td></td>
<td>100</td>
<td>Thin bed of silty fine sand.</td>
</tr>
<tr>
<td>50</td>
<td>CC 8</td>
<td></td>
<td></td>
<td>100</td>
<td>Very moist, gray-brown, silty fine SAND (SM); trace fine gravel, sub-rounded, rapid dilatancy (Qpgf).</td>
</tr>
<tr>
<td>60</td>
<td>CC 9</td>
<td></td>
<td></td>
<td>100</td>
<td>Very moist, gray, slightly silty, slightly gravelly, fine to medium SAND (SP-SM); (Qpgf).</td>
</tr>
</tbody>
</table>
Stiff, moist, brownish-gray slightly clayey, slightly sandy SILT (ML); trace gravel, fine organics, iron oxide staining, diamictic structure, paleosol (Qpgd).

Very moist, brownish-gray, fine SAND (SP); trace silt and medium sand (Qpgf).

Becomes fine to medium sand, trace silt.

Thin bed of silty fine sand.
Trace fine, sub-rounded gravel.

Very moist, brownish-gray, silty, fine SAND (SM); trace fine gravel, grading to fine to medium sand (Qpgf).

Dense, moist, gray, silty fine to medium SAND (SM); trace fine angular gravel, diamicitic structure (Qpgl).

Hard, moist, gray, CLAY (CH); interbedded with laminations and lenses of clayey silt, medium to high plasticity (Qpgl).

Hard, moist, gray clayey SILT (MH); high plasticity (Qpg1).

Hard, moist, gray CLAY (CH); with lenses of clayey silt, high plasticity, massive (Qpgl).
Fine gravel dropstones from 167' to 180'.

Terminated boring at 180 feet below ground surface.

PP = 4.3 tsf
weak reaction to HCl
PP > 4.5 tsf
Fill (Af).

0' to 8' vacuum drilled - no sample collected.

8' to 10.5' hand augered - no sample collected.

Hammer test 20'

Hammer test 30'

Medium dense, moist, brown, slightly gravelly, slightly silty to silty SAND (SM); fine to medium sand, fine subangular to subrounded gravel (Qvr).

SA

Very dense, moist, gray-brown, silty sandy GRAVEL (GM); fine to medium sand, fine to coarse subangular gravel, iron oxide staining (Qvtm).
<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>21-27-30</td>
<td>SPT 3</td>
<td>100</td>
<td></td>
<td>Very dense, moist, gray-brown, silty SAND (SM); trace gravel, fine sand, thin beds of fine sand (SP), laminations of silt, occasional organics (Qpgf).</td>
</tr>
<tr>
<td>45</td>
<td>30-31-46</td>
<td>SPT 4</td>
<td>100</td>
<td></td>
<td>Sand grades fine to coarse, gravelly.</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hammer test 40', Pressure meter test 40' to 46' - no sample collected.</td>
</tr>
<tr>
<td>25</td>
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<td></td>
<td>Hammer test 50'</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SA</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hammer test 60', Pressure meter test 60' to 66' - no sample collected.</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Mostly slough.</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hammer test at 70'.</td>
</tr>
</tbody>
</table>

**Graphical Log:**

- **USCS**
  - SM
  - SP-SM

**Remarks and Tests:**

- Very dense, moist, gray-brown, slightly silty SAND (SP-SM); trace gravel, fine to medium sand (Qpgf).
Sample grading more gravelly with depth.

Very moist.

Frequent thin laminations of fine sandy silt.

Very dense, very moist, gray-brown, slightly gravelly, silty SAND (SM); fine to medium sand, diamicitic structure (Qpgtm).

Very dense, very moist, brownish gray, slightly silty, SAND (SP-SM); fine to medium sand (Qpgf).

Hammer test 80'

CT

Hammer test 90'

SA

Hammer test 100'

CT

Hammer test 110'
Log of Boring UL-551

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>9</td>
<td>SPT 9</td>
<td>60-50/3°</td>
<td>67</td>
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<td>SP-SM</td>
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<tr>
<td>10</td>
<td>SPT 10</td>
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<td>100</td>
<td></td>
<td>No gravel.</td>
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<tr>
<td>11</td>
<td>SPT 11</td>
<td>81</td>
<td>100</td>
<td></td>
<td>Very dense, moist, brownish-gray, silty SAND (SM); trace fine subangular gravel, fine sand, occasional organics (Qpdf).</td>
</tr>
<tr>
<td>12</td>
<td>SPT 12</td>
<td>39-50/3°</td>
<td>100</td>
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<tr>
<td>13</td>
<td>SPT 13</td>
<td>36-50/4°</td>
<td>60</td>
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<td>14</td>
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<td>64</td>
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<td>15</td>
<td>SPT 15</td>
<td>39-50/0°</td>
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</tbody>
</table>

Groundwater Level: Hammer test 120'
Terminated boring at 191.5 feet below ground surface.

Grades gray.

Gravelly zone from 157’ to 158’.

Gray, some iron oxide staining.

Hard, moist, gray, silty CLAY (CL); medium plasticity, massive (Qpgl).

Few small inclusions of silt.

PP > 4.5 tsf, Sample slightly disturbed by drilling.
Hole was hand excavated using forced air to 7'. No samples were taken to this depth.
**Log of Boring UL-552**

**Project:** Sound Transit / University Link Light Rail  
**Project Location:** Seattle Washington  
**Contract Number:** RTA/LR 8-06

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>RETAINED INTERVAL</th>
<th>BLOW COUNTS</th>
<th>RECOVERY %</th>
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<td>30</td>
<td>45</td>
<td>SP</td>
<td>SP</td>
<td></td>
<td>100</td>
<td>Dense, moist, brown-gray, fine to medium SAND (SP); trace silt (Qpgf).</td>
</tr>
<tr>
<td>25</td>
<td>45</td>
<td>SP-SM</td>
<td></td>
<td></td>
<td></td>
<td>Dense, moist, brown-gray, slightly silty, fine SAND (SP-SM); trace medium sand (Qpgf).</td>
</tr>
<tr>
<td>25</td>
<td>45</td>
<td>SP-SM</td>
<td></td>
<td></td>
<td></td>
<td>Thin bed of silty, fine SAND / fine, sandy SILT.</td>
</tr>
<tr>
<td>25</td>
<td>45</td>
<td>SM/ML</td>
<td></td>
<td></td>
<td></td>
<td>Very moist to wet, gray, silty fine SAND to fine sandy SILT (SM/ML); rapid dilatancy (Qpgl).</td>
</tr>
<tr>
<td>25</td>
<td>45</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
<td>Stiff, moist, gray, trace to slightly clayey SILT (ML); trace fine, round gravel dropstones (Qpgl).</td>
</tr>
</tbody>
</table>

**Terminated boring at 50 feet below ground surface.**

**Hole was backfilled with bentonite chips.**

**Groundwater Level**

- **SA**
- **PP = 1.5 tsf**

---

**Northlink Transit Partners**  
401 South Jackson Street  
Seattle, Washington 98104
**Geotechnical Consultant**

NORTHLINK TRANSIT PARTNERS

Logged By: N. Reese

Checked By: ZN/SHE/HHH/DHM

**Date(s) Drilled**


**Geotechnical Consultant**

NORTHLINK TRANSIT PARTNERS

Logged By: N. Reese

Checked By: ZN/SHE/HHH/DHM

**Location**

STA. 1207+86 / -100 ft

**Coordinates**

N 540583 E 1577971

**Elevation Source**

SURVEY

**Total Depth of Borehole**

50 ft

**Hammer Weight/Drop (lb/in.)**

-

**Ground Surface Elevation/Datum**

68.0 ft / NAVD 88

**Drilling Method/Rig Type**

Sonic / Truck Mounted

**Drilling Contractor**

Boart Longyear

**Groundwater Level**

GRAPHIC LOG

**Groundwater Level**

USCS

**Remarks and Tests**

*Hole was hand excavated using forced air to 5.5', no samples were taken.*

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
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</thead>
<tbody>
<tr>
<td>65</td>
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<td>CC 1</td>
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<td>100</td>
<td>Asphalt parking lot.</td>
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<tr>
<td></td>
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<td></td>
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<td></td>
<td>Fill (A1).</td>
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<tr>
<td>60</td>
<td>5</td>
<td>CC 2</td>
<td></td>
<td>100</td>
<td>Dense, moist, gray, gravelly, silty SAND (SM); fine to coarse gravel, subrounded to subangular, fine to coarse sand, moderately weathered to 10.5' (Qvtm).</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Iron oxide staining.</td>
</tr>
<tr>
<td>55</td>
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<td>CC 3</td>
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<td>100</td>
<td>Friable, gray-brown, fine to medium sand, trace coarse sand.</td>
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<tr>
<td>50</td>
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<td>Intermittent thin beds of clean gravelly sand.</td>
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<tr>
<td>45</td>
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<td>Becomes gray-brown, silty fine sand, homogenous from 17' to 20'.</td>
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<tr>
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<td>Very dense, moist, slightly gravelly, silty, fine to medium sand from 20' to 21.5'.</td>
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<td>Gravelly, fine to coarse gravel, subrounded to subangular, trace coarse sand, very friable from 21.5' to 34'.</td>
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<td>5</td>
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<td>Bed of slightly silty, fine to medium sand.</td>
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<td>25</td>
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<td>ELEVATION (ft)</td>
<td>SAMPLE INTERVAL</td>
<td>TYPE/NUMBER</td>
<td>RETAINED INTERVAL</td>
<td>BLOW COUNTS</td>
<td>RECOVERY %</td>
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<td>CC 8</td>
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NR
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No Sample (Af).

CC 1
100

Slightly moist, gray-brown, gravelly, silty, SAND (SM); fine to medium sand, fine to coarse, subrounded gravel (Af).
Numerous medium-dense till-like pieces.

6 in

SA, CT

Thin dark brown zone, possibly mixed in topsoil.
Till-like pieces becoming more dense below 13'.

CC 2
100

Dense, slightly moist, gray, silty, gravelly SAND (SM); fine to medium sand, fine to coarse, subrounded gravel (Qvt).
Color grades to brownish-gray.

SA, CT

CC 3
100

Moist, gray-brown, slightly silty, gravelly SAND (SM); fine subrounded gravel, fine to medium sand, trace coarse sand, occasional pieces of till (Qvtm).
Moist, gray-brown, gravelly, silty SAND (SM); fine to medium sand, fine subrounded gravel (Qvt).

Moist, gray-brown, gravelly, silty SAND (SM); fine to medium sand, predominantly fine sand, fine subrounded gravel (Qvtm).

Very moist, sand becoming more coarse.

Very moist, gray, slightly silty, sandy GRAVEL (GP-GM); (Qvtm).

Wet, gray-brown, slightly silty, gravelly, SAND (SP-SM) (Qvtm).

Wet, gray-brown, sandy SILT to silty SAND (SM/ML); medium to coarse subrounded sand (Qpgf).

Wet, gray, sandy GRAVEL (GW); fine to medium sand, fine to coarse, subrounded gravel, trace coarse sand (Qpgf).

Moist, light gray-brown, slightly gravelly, silty SAND (SM); fine subrounded gravel, fine sand, thin laminations of clayey silt (Qpgf).
<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>RETAINED INTERVAL</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
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<tr>
<td>0</td>
<td>80</td>
<td>SP</td>
<td></td>
<td></td>
<td>100</td>
<td>Wet, gray, slightly silty, gravelly SAND (SP); trace fine rounded gravel, fine to medium sand, trace coarse sand (Qpgf).</td>
</tr>
</tbody>
</table>

Terminated boring at 80 feet below ground surface.
Hole vacuum drilled from 0' to 8'; no samples were taken.

Asphalt parking lot.

- Fill containing silty SAND, gravel, concrete debris.
- Dense, moist, gray-brown, gravelly, silty, fine to medium SAND (SM); fine to coarse, sub-rounded gravel (Qvtm).
- Medium dense, moist, gray silty, well graded SAND from 14' to 16'.
- Thin bed of gravelly, sandy SILT (ML), moist, diamict.
- Very friable.
- Dense, moist, brown-gray, fine to medium SAND (SP); trace silt (Qvtm).
- Dense, moist, brown-gray SAND (SW); well graded, fine to coarse, homogenous (Qvtm).
- Grades to slightly silty, trace gravel.
Thin lens of silt.
Very dense, dry, gray-brown, gravelly, silty, fine to medium SAND (SM); fine to coarse gravel, sub-angular to sub-rounded (Qpgtm).

Dense, moist, gray-brown, fine to medium SAND (SP); trace gravel, trace silt (Qpgf).

Grades to fine SAND (SP); trace medium sand and gravel.

Dense, moist gray SILT (ML); thinly laminated, with thin sand interbeds (Qpgf).

Dense, moist, gray-brown fine to medium SAND (SP); trace silt, trace gravel (Qpgf).

Terminated boring at 51 feet below ground surface.
### Log of Boring UL-557

**Project:** Sound Transit / University Link Light Rail  
**Project Location:** Seattle, Washington  
**Contract Number:** RTA/LR 8-06

<table>
<thead>
<tr>
<th>Date(s) Drilled</th>
<th>Sonic / Truck Mounted</th>
<th>Boart Longyear</th>
<th>Total Depth of Borehole</th>
<th>Elevation Source</th>
<th>Ground Surface Elevation/Datum</th>
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<tbody>
<tr>
<td>7/13/2007 - 7/13/2007</td>
<td>Sonic / Truck Mounted</td>
<td>Boart Longyear</td>
<td>50 ft</td>
<td>SURVEY</td>
<td>80.1 ft / NAVD 88</td>
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</tbody>
</table>

**Core Diameter:** 4 in  
**Hammer Weight/Drop:** -  
**Location:** STA. 1211+26 / -393 ft  
**Coordinates:** N 540932 E 1577680  
**Elevation Source:** SURVEY

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Sample Interval</th>
<th>Type/Number</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>Recovery %</th>
<th>Graphic Log</th>
<th>USCS</th>
<th>Material Description</th>
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<tr>
<td>70</td>
<td>10</td>
<td>SM</td>
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<td>Medium dense to dense, moist, gray-brown silty SAND; iron oxide stained (Af).</td>
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<tr>
<td>65</td>
<td>15</td>
<td>SM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dense, moist, gray gravelly, silty SAND (SM) (Qvt).</td>
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<tr>
<td>60</td>
<td>20</td>
<td>SM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dense, moist, brown-gray, gravelly, silty SAND (SM); fine to medium sand, fine to coarse gravel, subangular to subrounded, trace coarse sand, trace iron oxide staining to 11’ (Qvtm).</td>
</tr>
<tr>
<td>55</td>
<td>25</td>
<td>SM</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very friable.</td>
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<tr>
<td>50</td>
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<td>SM</td>
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<td>Becomes very dense.</td>
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<tr>
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<td>80</td>
<td>SM</td>
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</tbody>
</table>

**Remarks:** Hole vacuum drilled from 0’ to 8’; no samples were taken.
Stiff, moist, gray-brown, fine sandy SILT (ML); trace gravel and clay, rapid dilatancy (Qpgl).

Interbeds of medium stiff sandy silt, thinly laminated, with wavy, disturbed texture from 45' to 47'.

Dense, moist, gray-brown, slightly silty SAND (SP-SM); fine to medium sand, trace clay, with thin beds of laminated, fine sandy, deformed silt (Qpgf).

Terminated boring at 50 feet below ground surface.
Hole was hand augered and vacuum drilled from 0' to 8'; no samples were taken.

Asphalt parking lot. Fill to around 4' (Af).

Moist, gray, gravelly, silty SAND (SM) (Qvt).

Dense, moist, gray-brown, slightly gravelly, silty SAND (SM); interbeds of silt, fine to medium sand, trace iron oxide staining (Qvtm).

Trace fine gravel.

Dense, moist, gray-brown, gravelly, silty SAND (SM); fine to medium sand, iron oxide mottling, paleosol (Qpgt).

Fine gray-brown, sandy SILT with iron oxide mottling from 20' to 21.5'.

Bed of moist, brown, gravelly SAND (SP); fine to medium sand, trace silty and coarse sand.

Stiff, moist, gray-brown, sandy SILT (ML); fine to medium sand, trace gravel (Qpgl).
Medium dense to dense, moist, gray-brown silty fine SAND and fine sandy SILT (SM/ML); slickensides in silt layers (Qpgl).

Stiff, moist to very moist, gray, fine sandy SILT (ML); slow dilatancy (Qpgl).

Dense, moist, gray, slightly clayey, slightly gravelly, slightly silty SAND (SP-SM); fine to coarse subrounded gravel, fine to medium sand, contains thin beds of silty, fine to coarse sand, beds of thinly laminated SILT, diamictic texture (Qpgtm).

Hard, moist, gray, slightly gravelly, sandy, silty CLAY (CL) (Qpgd).

Hard, moist, gray, slightly gravelly, sandy, silty CLAY (CL-CH); occasional fine organics, thin, deformed interbeds of clayey silt, massive to disturbed laminations, occasional slickensides (Qpgl).

PP > 4.5 tsf
Project: Sound Transit / University Link Light Rail  
Project Location: Seattle Washington  
Contract Number: RTA/LR 8-06

Log of Boring UL-558  
Sheet 3 OF 3

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>RETAINED INTERVAL (N VALUE)</th>
<th>RECOVERY %</th>
<th>GRAPHIC LOG</th>
<th>MATERIAL DESCRIPTION</th>
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<td>CC 7</td>
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</tbody>
</table>

MATERIAL DESCRIPTION:
- Groundwater Level
- PP > 4.5 tsf
- PP > 4.5 tsf

Terminated boring at 95 feet below ground surface.

Northlink Transit Partners  
401 South Jackson Street  
Seattle, Washington 98104

Boring UL-558  
Sheet 3 OF 3
Hole vacuum drilled from 0’ to 10’; no samples were collected.

Asphalt parking lot.

Moist, gray, gravelly silty SAND (SM) (Af).

Dense, moist, mottled gray-brown and gray sandy SILT (ML); trace clay, trace sub-rounded, fine gravel, occasional fine organics, trace iron oxide staining, thin lenses of medium to coarse sand and silty sand (Qvtm).

Moist, gray-brown, slightly gravelly SAND (SP); trace silt, fine, subrounded gravel, fine to medium sand (Qvtm).

Dense, moist, brown silty SAND (SM); trace medium to coarse sand and gravel, fine sand, paleosol (Qpgf).

Dense, moist, brown silty SAND (SM); trace subrounded fine gravel, fine to medium sand (Qpgf).
Grades to fine sand with trace silt.

Stiff, moist to very moist, brownish-gray, fine sandy SILT (ML); rapid dilatancy (Qpgl).

Grades to gray.

Dense, very moist, gray, slightly sandy SILT (ML); trace iron oxide staining, thin lenses of gray, fine to medium SAND, rapid dilatancy (Qpgl).

Thin lenses of gray, coarse sand at 54' and 55'.

Hard, moist, gray sandy, silty CLAY (CL); trace fine gravel, diamictic texture (Qpgd).

Slightly gravelly from 60' to 63.5'.

18" thick bed of SILT.

Hard, moist, olive-gray, slightly silty CLAY (CL); medium plasticity (Qpgl).

Very dense, moist, gray SILT (ML); trace gravel dropstones, trace clay, fine to coarse sand, rapid dilatancy (Qpgl).

Hard, moist, gray, gravelly, silty CLAY (CL); thin laminations of gray, silty, fine to medium SAND at 69' (Qpgl).

Hard, moist, gray, gravelly, sandy, silty CLAY (CL) (Qpgd).

Lamination of gravelly, silty fine SAND.

Dense, very moist, gray SILT (ML); trace fine sand and clay.
### Log of Boring UL-559

**ELEVATION (ft)**

<table>
<thead>
<tr>
<th>Depth</th>
<th>ML</th>
<th>SM</th>
<th>SM/ML</th>
<th>SM</th>
<th>CL</th>
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</tbody>
</table>

**MATERIAL DESCRIPTION**

- **ML (Qpgl)**
  - Dense, moist, gray, gravelly, silty SAND (SM); fine to coarse, sub-rounded gravel, with intermittent lenses of gravelly, medium to coarse SAND, thinly laminated SILT, silty fine SAND, and pieces of clay, and gray, silty, sandy CLAY, diamict (Qpgd).

- **SM (Qpgl)**
  - Clayey, gravelly, silty SAND; diamict (Qpgd).

- **SM/ML (Qpgl)**
  - Dense, moist, gray, silty fine SAND to fine sandy SILT (SM/ML) (Qpgl).

- **SM (Qpgl)**
  - Bed of silty, gray SAND.

- **SM (Qpgd)**
  - Dense, moist, gray, gravelly, clayey, silty SAND (SM); diamict (Qpgd).

- **CL (Qpgl)**
  - Hard, moist, gray CLAY (CL); trace to slightly silty, medium plasticity, thinly laminated to massive, disturbed laminations, occasional small slickensides (Qpgl).

- **CT (Qpgd)**
  - Occasional high angle slickensides.

- **SA (Qpgd)**
  - **PP = 4.5 tsf**
  - **MC, AL**
  - **PP > 4.5 tsf**

Terminated boring at 110 feet below ground surface.
**Asphalt parking lot.**

Moist, gray, gravelly, silty SAND (SM) (Af).

---

Dense, moist, gray, gravelly, silty SAND (SM); fine to medium sand, trace iron oxide staining (Qvt).

---

Dense, moist, brown, grading to brown-gray, gravelly, silty SAND (SM); fine to coarse subrounded gravel, fine to medium sand, cobbles to 1’ inferred from drilling (Qvtm).

Thin, friable sand bed.

Hole was hand augered and vacuum drilled from 0’ to 10’, no samples were taken.
### Log of Boring UL-560

#### Project: Sound Transit / University Link Light Rail
**Project Location:** Seattle Washington
**Contract Number:** RTA/LR 8-06

#### U-LINK BORINGS UNIVERSITY LINK PROGRESS.GPJ UNIVERSITY LINK PROGRESS.GPJ 06/24/08 REV-3

**Northlink Transit Partners**
401 South Jackson Street
Seattle, Washington 98104

---

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>TYPE/NUMBER</th>
<th>SAMPLE INTERVAL</th>
<th>RETAINED INTERVAL</th>
<th>RECOVERY %</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>CC 7</td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td>Dense, moist to very moist, gray-brown, gravelly SAND (SP); fine, subrounded gravel, fine to medium sand, trace coarse sand (Qpgf).</td>
</tr>
<tr>
<td>40</td>
<td>CC 8</td>
<td></td>
<td></td>
<td>100</td>
<td>SP</td>
<td>Scattered lenses of silty sand diamict and silt scattered through out sand.</td>
</tr>
<tr>
<td>50</td>
<td>CC 9</td>
<td></td>
<td></td>
<td>100</td>
<td>GM</td>
<td>Dense, very moist, gray-brown, slightly silty, sandy GRAVEL (GM) (Qpgf). Bed of gravelly silty SAND diamict from 52.5' to 54'.</td>
</tr>
<tr>
<td>60</td>
<td>CC 10</td>
<td></td>
<td></td>
<td>100</td>
<td>SM</td>
<td>Dense, moist, brown-gray, gravelly, silty SAND (SM); fine to medium sand (Qpgf).</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>Dense, moist, brown-gray, fine SAND (SP); trace gravel, medium sand and trace silt (Qpgf).</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td>Dense, moist, gray, silty, fine SAND (SM) (Qpgf).</td>
</tr>
</tbody>
</table>

---

**Boring UL-560**

**Sheet 2 OF 4**
Hard, moist, gray, slightly sandy, silty CLAY (CL); trace gravel, diamicitic texture, medium plasticity, with interbedded thin lenses of clayey silt and clay (Qpgd).

Dense, moist, gray, silty SAND (SM); fine to medium sand (Qpgf).

Dense, moist, gray, gravelly, silty SAND (SM); fine to medium sand (Qpgt).

Dense, moist, gray-brown, gravelly SAND (SP); trace silt, interbedded lenses of slightly silty fine to coarse sand (Qpgf).

Occasional pieces of gravelly, silty, fine to medium SAND; diamicit.

Hard, moist, gray, silty CLAY (CL); trace fine gravel, slow to medium dilatancy, massive, interbedded with dense, moist, gray, gravelly, silty SAND (Qpgd).

Thin interbeds of silty fine SAND and fine sandy SILT from 111' to 114'.

MC, CT

PP > 4.5 tsf

PP = 3.8 tsf
Hard, moist, gray, silty CLAY (CL); occasional very thin silt laminations, high plasticity, massive (Qpgl).

Occasional high angle slickensides.

Terminated boring at 140 feet below ground surface.
Hole was excavated to 9' using an air-knife and hand augers; no samples were taken.
Thin bed of wet, silty, sandy GRAVEL.

Dense, moist to very moist, gray-brown, gravelly, silty SAND (SM); thin interbeds of laminated silt and silty sand, diamict pieces mixed in, fine to coarse subrounded gravel (Qvtm).

Dense, very moist, gray-brown, fine to medium SAND (SP); trace silt, trace coarse sand and fine gravel (Qpgf).

Very moist, gray-brown, slightly silty, fine SAND (SP-SM); trace medium sand, occasional thin seams of clayey silt, grades to slightly gravelly, silty, fine to medium SAND (SM) (Qpgf).
No gravel from 80' to 90'.

Trace silt.

Becomes slightly gravelly, fine, subrounded. Intermittent thin beds of silty clay, medium plasticity, rapid dilatancy from 104' to 118'.

Hard, moist, gray, silty CLAY (CL) (Qpgl).

Dense, wet, gray, slightly silty, fine SAND (SM/ML); fine sand with medium beds of SILT (ML); (Qpgf)

Thin bed of silty clay.
Terminated boring at 140 feet below ground surface.

Hole was abandoned by backfilling with bentonite chips, with a cement patch at the surface.

Moist, gray, silty, fine SAND (SM) (Qpgf).

Moist, gray, slightly clayey SILT (ML) (Qpgl).

Hard, moist, gray, silty CLAY (CL); occasional interbeds of clayey SILT, disturbed, disturbed laminations to massive (Qpgl).

Occasional high angle slickensides.

Moist, gray, silty, fine SAND (SM) (Qpgf).
Boring was hand excavated to 11' using an air-knife; no samples were taken.

Asphalt parking lot.

Well graded, silty SAND fill to 11' (Af).

Dense, moist, gray-brown, gravelly, silty SAND (SM); fine to medium sand, trace coarse locally, fine to coarse gravel, sub-angular to sub-rounded (Qvt).

Grades to brownish-gray.

Becomes very dense.
<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>TYPE/NUMBER</th>
<th>SAMPLE INTERVAL</th>
<th>BLOW COUNTS (N-VALUE)</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>CC 4</td>
<td>40</td>
<td>100</td>
<td>USCS</td>
<td>Grades to gray.</td>
</tr>
<tr>
<td>40</td>
<td>CC 5</td>
<td>50</td>
<td>100</td>
<td>SM</td>
<td>Becomes wet, grades to brownish gray from 41' to 50'.</td>
</tr>
<tr>
<td>50</td>
<td>CC 6</td>
<td>60</td>
<td>100</td>
<td>SM</td>
<td>Dense, very moist, gray-brown, silty gravelly SAND (SM); with thin interbeds / pieces of till (Qvtm).</td>
</tr>
<tr>
<td>60</td>
<td>CC 7</td>
<td>70</td>
<td>100</td>
<td>SW</td>
<td>Medium dense to dense, very moist, brown SAND (SW); trace silt; fine to coarse sand, homogenous (Qpgf).</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very moist to wet, light gray-brown, fine silty SAND (SM); faint iron oxide staining at 59', occasional thin beds of medium sand and sandy silt (Qpgf).</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Becomes wet, trace fine gravel.</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
<td>ML</td>
<td>Dense, moist, light brown, fine, sandy SILT (ML); trace fine, angular gravel, wet and stiff, moist brown SILT (ML); scattered, very thin laminated with silty clay, medium plastic, lightly iron oxide stained (Qpgl).</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td>Dense, moist, mottled light and dark gray, gravelly, silty, fine to medium SAND (SM); fine to coarse gravel, diamicitic texture (Qpgt).</td>
</tr>
<tr>
<td>110</td>
<td></td>
<td></td>
<td></td>
<td>SM/ML</td>
<td>Gray, interbedded silty fine SAND and fine sandy SILT (SM/ML);</td>
</tr>
</tbody>
</table>

Log of Boring UL-562

Northlink Transit Partners
401 South Jackson Street
Seattle, Washington 98104

Boring UL-562
Sheet 2 OF 5
<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>RETAINED INT. EL.</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>SM/ML</td>
<td></td>
<td>100</td>
<td>SP</td>
<td>trace gravel, disturbed laminations (Qpgl).</td>
</tr>
<tr>
<td>-15</td>
<td>CC 8</td>
<td></td>
<td></td>
<td></td>
<td>85</td>
<td>SP</td>
<td>Moist to wet, gray-brown, fine to medium SAND (SP); trace gravel, trace silt (Qpgf).</td>
</tr>
<tr>
<td>-20</td>
<td>CC 9</td>
<td></td>
<td></td>
<td></td>
<td>90</td>
<td>SP</td>
<td>Bed of gravelly sand, then becomes wet, fine SAND.</td>
</tr>
<tr>
<td>-25</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95</td>
<td>SP</td>
<td>Dense, moist to wet, gray-brown, fine SAND (SP); trace gravel, trace fine sand, trace silt (Qpgf).</td>
</tr>
<tr>
<td>-30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100</td>
<td>SP</td>
<td>Occasional thin beds of brown, laminated SILT.</td>
</tr>
<tr>
<td>-35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>Becomes moist to very moist, brown, fine to medium SAND.</td>
</tr>
<tr>
<td>-40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>Occasional thin beds of medium SAND from 89' to 93'.</td>
</tr>
<tr>
<td>-45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>Dense, moist to wet, gray-brown, slightly gravelly, slightly silty, fine to medium SAND (SP-SM); trace coarse sand, fine to coarse, sub-rounded gravel (Qpgf).</td>
</tr>
<tr>
<td>-50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td>Dense, moist to wet, gray-brown, slightly silty to silty SAND (SP-SM); trace gravel, trace medium sand (Qpgf).</td>
</tr>
</tbody>
</table>

**REMARKS AND TESTS**

- Boring UL-562
- Project: Sound Transit / University Link Light Rail
- Project Location: Seattle, Washington
- Contract Number: RTA/LR 8-06
Dense, moist to wet, gray-brown, silty SAND (SM) (Qpgf).

6" bed of till-like, dense, silty sand, with trace fine gravel, diamictic texture.

Dense, moist, slightly silty SAND (SP-SM) (Qpgf).

Grades to silty, fine to medium SAND (SM); trace fine gravel.

Dense, moist, gray-brown, silty fine to medium SAND (SM); trace fine gravel diamict (Qpgtm).

Dense, moist, gray-brown, slightly silty, fine SAND (SP-SM); trace medium sand, trace gravel (Qpgf).

Inclusions of dense, moist, gray-brown, slightly gravelly silty SAND (SM); fine to medium sand, fine, angular gravel, diamict.
Hard, moist, gray, silty CLAY (CL); massive with occasional thin, faint, disturbed, laminations, high plasticity (Qpgl).

Occasional slickensides.

Terminated boring at 173 feet below ground surface.

Weak reaction to HCl.

Boring was abandoned using bentonite as backfill, with a cement patch in place at the surface.
**Log of Boring UL-565**

**Date(s) Drilled:** 7/31/2007 - 8/1/2007

**Geotechnical Consultant:** NORTHLINK TRANSIT PARTNERS

**Logged By:** N. Reese

**Total Depth of Borehole:** 175 ft

**Drilling Method/ Rig Type:** Sonic / Truck Mounted

**Drilling Contractor:** Boart Longyear

**Hammer Weight/Drop (lb/in.):** -

**Ground Surface Elevation/Datum:** 66.4 ft / NAVD 88

**Core Diameter:** 6 in

**Coordinates:** N 540852    E 1578054

**Elevation Source:** SURVEY

**Core Diameter:** 6 in

**Location:** STA. 1210+77 / -9 ft

**Core Diameter:** 6 in

**Coordinates:** N 540852    E 1578054

**Elevation Source:** SURVEY

---

### ELEVATION (ft)

<table>
<thead>
<tr>
<th>Depth</th>
<th>Type/Number</th>
<th>Sample Interval</th>
<th>Retained Interval</th>
<th>Blow Counts</th>
<th>Recovery %</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>SP-SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Brick pavers at surface.</td>
</tr>
<tr>
<td>60</td>
<td>SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Silty to poorly graded SAND (SP-SM); graded to well graded SAND at 7' (Af).</td>
</tr>
<tr>
<td>55</td>
<td>SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Medium dense to dense, moist, gray-brown, gravelly, fine to medium silty SAND (SM); trace coarse sand, light iron oxide staining, fine to coarse subrounded gravel (Qvtm).</td>
</tr>
<tr>
<td>50</td>
<td>SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Dense, moist, gray, silty SAND (SM); trace fine gravel, fine sand, faint laminations, scattered lenses of diamicitic silty sand, coarse sand, laminated silt, non-plastic fines (Qvtm).</td>
</tr>
<tr>
<td>45</td>
<td>SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Dense, moist, gray-brown, gravelly, silty, fine to medium SAND (SM); fine to coarse gravel, subangular to subrounded, light iron oxide staining (Qvt).</td>
</tr>
<tr>
<td>40</td>
<td>SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Dense, very moist, gray-brown, gravelly, silty, fine to medium SAND (SM); intermittent thin lenses of silty fine sand (Qvtm).</td>
</tr>
<tr>
<td>35</td>
<td>SM</td>
<td>5</td>
<td></td>
<td>100</td>
<td></td>
<td>Hole hand augered and vacuum drilled from 0' to 8'; no samples were taken.</td>
</tr>
</tbody>
</table>

---

**Northlink Transit Partners**

401 South Jackson Street

Seattle, Washington 98104
Dense, moist, gray-brown, silty to medium SAND (SM); trace fine gravel, intermittent thin lenses of coarse sand and slightly silty fine sand (Qpgf).

Thin bed with iron oxide staining.

Wet from 45' to 49'.

Thin beds of silt and medium to coarse sand from 49' to 58'.

Thin bed of medium to coarse sand.

Gray-brown SILT (ML); trace fine sand and clay (Qpgl).

Dense, moist, gray-brown, silty, fine SAND (SM) (Qpgl).

Stiff, moist, gray-brown, laminated SILT (ML) (Qpgl).

Dense, moist, gray-purple, gravelly, silty SAND (SM); fine, subrounded gravel, brecciated texture (Qpgt).

Dense, very moist, brown, slightly silty fine to medium SAND (SP-SM); trace gravel, non-plastic fines, interbedded with silt beds (Qpgf).
<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>TYPE/NUMBER</th>
<th>RECOVERY %</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>SW</td>
<td>80</td>
<td>Dense, very moist, brownish-gray, slightly gravelly, fine to coarse SAND (SW); trace silt (Qpgf).</td>
</tr>
<tr>
<td>90</td>
<td>SM</td>
<td></td>
<td>Dense, very moist, brownish-gray silty SAND (SM); fine to coarse sand (Qpgf).</td>
</tr>
<tr>
<td>90</td>
<td>SM</td>
<td></td>
<td>Becomes gray.</td>
</tr>
<tr>
<td>90</td>
<td>SP-SM</td>
<td>90</td>
<td>Dense, very moist, brown-gray, slightly gravelly, slightly silty, fine to medium SAND (SP-SM); fine to coarse, sub-rounded gravel, thin beds of silty fine SAND (Qpgf).</td>
</tr>
<tr>
<td>90</td>
<td>GP</td>
<td></td>
<td>Gravelly SAND; trace silt.</td>
</tr>
<tr>
<td>90</td>
<td>SM</td>
<td></td>
<td>Increasing fine, subangular gravel.</td>
</tr>
<tr>
<td>90</td>
<td>SM</td>
<td></td>
<td>Dense, moist, brown-gray, silty SAND (SM); trace fine, sub-rounded gravel, weathered, possible paleosol (Qpgd).</td>
</tr>
<tr>
<td>90</td>
<td>GP</td>
<td></td>
<td>Dense, very moist, brown-gray, very sandy GRAVEL (GP); trace silt, fine to coarse, sub-rounded gravel (Qpgf).</td>
</tr>
</tbody>
</table>

**Northlink Transit Partners**
401 South Jackson Street
Seattle, Washington 98104
**Log of Boring UL-565**

**Project:** Sound Transit / University Link Light Rail  
**Project Location:** Seattle, Washington  
**Contract Number:** RTA/LR 8-06

---

<table>
<thead>
<tr>
<th>ELEVATION (ft)</th>
<th>SAMPLE INTERVAL</th>
<th>TYPE/NUMBER</th>
<th>BLOW COUNTS (N VALUE)</th>
<th>RECOVERY %</th>
<th>GRAPHIC LOG</th>
<th>USCS</th>
<th>MATERIAL DESCRIPTION</th>
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<tbody>
<tr>
<td>-50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>GP</td>
<td></td>
<td>Dense, moist, brown-gray, gravelly, fine to medium SAND (SP); trace silt, fine to coarse, sub-rounded gravel (Qpgf).</td>
</tr>
<tr>
<td>-55</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP</td>
<td></td>
<td>Dense, moist, gray, slightly gravelly, very silty SAND (SM); fine to coarse, sub-rounded to sub-angular gravel, diamictic texture (Qpgtm).</td>
</tr>
<tr>
<td>-60</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td></td>
<td>Dense, moist, brown-gray, slightly gravelly, slightly silty, fine to medium SAND (SP-SM); occasional beds of fine to coarse sand (Qpgf).</td>
</tr>
<tr>
<td>-65</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP-SM</td>
<td></td>
<td>Thin bed of diamictic, silty sand, with trace fine gravel.</td>
</tr>
<tr>
<td>-70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td></td>
<td>Diamict bed.</td>
</tr>
<tr>
<td>-75</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SP-SM</td>
<td></td>
<td>Dense, moist, gray-brown to gray-purple, slightly gravelly, silty, fine to medium SAND (SM); fine to coarse gravel, diamictic texture (Qpgtm).</td>
</tr>
<tr>
<td>-80</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SM</td>
<td></td>
<td>Hard, moist, gray CLAY (CL); scattered thin interbeds of clayey silt, medium to high plasticity, massive (Qpgf).</td>
</tr>
<tr>
<td>-85</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CL</td>
<td></td>
<td>Occasional slickensides.</td>
</tr>
<tr>
<td>-90</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-95</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
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<tr>
<td>-105</td>
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<td></td>
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</tr>
</tbody>
</table>

**Groundwater Level**

-45 ft

**Remarks and Tests**

- Reaction to HCl: PP > 4.5 tsf

**Log of Boring UL-565**

Northlink Transit Partners  
401 South Jackson Street  
Seattle, Washington 98104

---

**Northlink Transit Partners**

401 South Jackson Street  
Seattle, Washington 98104
### Log of Boring UL-565

**Project:** Sound Transit / University Link Light Rail  
**Project Location:** Seattle, Washington  
**Contract Number:** RTA/LR 8-06

#### Materials:
- **CC 12**: 100% recovery
  - 4" fractured zone.  
- **CC 13**: 100% recovery
  - Reaction to HCl
  - PP > 4.5 tsf
  - Hole was backfilled with bentonite chips and brick pavers were replaced at the surface.

#### Boring Details:
- **Terminated boring at 175 feet below ground surface.**
### SOIL DESCRIPTION

<table>
<thead>
<tr>
<th>Depth, Ft.</th>
<th>Symbol</th>
<th>Pct, Pnm</th>
<th>Samples</th>
<th>Ground</th>
<th>Water</th>
<th>Depth, Ft.</th>
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<td></td>
<td></td>
<td></td>
<td>20</td>
</tr>
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</tr>
<tr>
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<td></td>
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<td>60</td>
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</tbody>
</table>

- **Dense to very dense, gray-brown, slightly gravelly, silty SAND; moist; scattered cobbles; (Qvt) SM.**
- **Very dense, gray-brown, silty, fine SAND; wet; (Qvd) SM.**
- **Very dense, gray-brown, slightly gravelly to gravelly, silty SAND; moist to wet; scattered cobbles, scattered seams of clayey sand and sandy silt near bottom; (Qvd) SM.**
- **Very dense, gray to dark gray, gravelly, silty, clayey SAND; moist; (Qp) SM.**
- **Very dense, gray, silty, gravelly SAND; wet; (Qp) SM.**
- **Hard, gray, silty CLAY; moist; scattered to abundant slickensides near top, scattered gravel locally, scattered cobbles inferred from drill action, abundant irregular silt seams and pockets, abundant seams of high-plasticity clay below 81 feet; (Qp) CL/CH.**

### NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.
2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.
3. Groundwater level, if indicated above, is for the date specified and may vary.
4. Refer to KEY for explanation of "Symbols" and definitions.
5. USCS designation is based on visual-manual classification and selected laboratory index testing.
The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.

1. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.

2. Groundwater level, if indicated above, is for the date specified and may vary.

3. Refer to KEY for explanation of "Symbols" and definitions.

4. USCS designation is based on visual-manual classification and selected laboratory index testing.

<table>
<thead>
<tr>
<th>Depth, Fl.</th>
<th>Symbol</th>
<th>FLU, ppm</th>
<th>Ground Water</th>
<th>Depth, Fl.</th>
</tr>
</thead>
<tbody>
<tr>
<td>110.0</td>
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<tr>
<td>139.0</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

BOTTOM OF BORING COMPLETED 09/16/2001

NOTES

1. The stratification lines represent the approximate boundaries between soil types, and the transition may be gradual.

2. The discussion in the text of this report is necessary for a proper understanding of the nature of the subsurface materials.

3. Groundwater level, if indicated above, is for the date specified and may vary.

4. Refer to KEY for explanation of "Symbols" and definitions.

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LOG OF BORING NB-389
UPDATED DECEMBER 2004

January 2005 21-1-08110-620

SHANNON & WILSON, INC. FIG. A.2-69
Geotechnical and Environmental Consultants Sheet 2 of 2
UL Boring Laboratory Results
UL-545
Daily Average Water Level Elevations (ft)

<table>
<thead>
<tr>
<th>Date</th>
<th>Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/5/07</td>
<td>29.8</td>
</tr>
<tr>
<td>7/19/07</td>
<td>26.89</td>
</tr>
<tr>
<td>8/2/07</td>
<td>24.37</td>
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<td>23.8</td>
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<td>8/30/07</td>
<td>22.6</td>
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<td>20.2</td>
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<td>2/14/08</td>
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<td>2/28/08</td>
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<td>6/5/08</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>54.8</td>
<td>17.8</td>
<td>--</td>
<td>--</td>
<td>26.89</td>
<td>24.37</td>
</tr>
</tbody>
</table>

VWP (Slope Indicator)
### Daily Average Water Level Elevations (ft)

<table>
<thead>
<tr>
<th></th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/5/07</td>
<td>54.8</td>
<td>-47.2</td>
<td>--</td>
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<td>24.96</td>
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<tr>
<td>7/10/07</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>07/10/07 12:00</td>
<td>06/06/08 15:03</td>
</tr>
</tbody>
</table>

Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

UL-545B

VWP (Slope Indicator)
SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>UL-545</td>
<td>CC-9</td>
<td>70.0-71.0</td>
<td>27.3</td>
<td>25</td>
<td>51</td>
<td>26</td>
<td>CH</td>
</tr>
<tr>
<td>■</td>
<td>UL-545</td>
<td>CC-10</td>
<td>75.0-76.0</td>
<td>27.3</td>
<td>25</td>
<td>47</td>
<td>22</td>
<td>CL</td>
</tr>
<tr>
<td>▲</td>
<td>UL-545</td>
<td>CC-11</td>
<td>86.0-87.0</td>
<td>29.0</td>
<td>28</td>
<td>51</td>
<td>23</td>
<td>CH</td>
</tr>
<tr>
<td>⚫</td>
<td>UL-545</td>
<td>CC-11</td>
<td>95.0-96.0</td>
<td>27.7</td>
<td>21</td>
<td>51</td>
<td>30</td>
<td>CH</td>
</tr>
</tbody>
</table>

Dashed line indicates the approximate upper limit boundary for natural soils.

Atterberg Limits Test Report (ASTM D-4318)
TEST RESULTS - BATCH 1 OF UNIVERSITY LINK SAMPLES

**Basis:**

**Remark:**
The testing was performed by use of modified SAT steel pieces, allowing testing of soil samples containing particles up to 4 mm. The development and use of modified steel pieces was published in the RETC 2007 proceedings. Percentages of sample material < 4.0 mm and < 1.0 mm are subsequent to the preparation according to the standard procedure for the SAT.

<table>
<thead>
<tr>
<th>Sample No. (given by SINTEF)</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-507 CC-19 125 – 130’</td>
<td>UL-507 CC-16 110 – 115’</td>
<td>UL-508 CC-20 120 – 125’</td>
</tr>
<tr>
<td>SAT Test 1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>SAT Test 2</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SAT (Mean)</td>
<td>0.5</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample No. (given by SINTEF)</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-508 CC-21 130 – 135’</td>
<td>UL-509 CC-6 79 – 84’</td>
<td>UL-509 CC-8 95 – 100’</td>
</tr>
<tr>
<td>SAT Test 1</td>
<td>0</td>
<td>1</td>
<td>26</td>
</tr>
<tr>
<td>SAT Test 2</td>
<td>0</td>
<td>2</td>
<td>26</td>
</tr>
<tr>
<td>SAT (Mean)</td>
<td>0.0</td>
<td>1.5</td>
<td>26.0</td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample No. (given by SINTEF)</th>
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<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-511 CC-7 50 – 55.0’</td>
<td>UL-511 CC-8 60 – 65’</td>
<td>UL-515 CC-6 65 – 70’</td>
</tr>
<tr>
<td>SAT Test 1</td>
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<td>9</td>
<td>0</td>
</tr>
<tr>
<td>SAT Test 2</td>
<td>27</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>SAT (Mean)</td>
<td>25.5</td>
<td>10.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>89.6 %</td>
<td>79.7 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>82.8 %</td>
<td>57.5 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample No. (given by SINTEF)</td>
<td>34</td>
<td>35</td>
<td>36</td>
</tr>
<tr>
<td>----------------------------</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-540 CC-19, 140 – 145’</td>
<td>UL-542 SS-7, CC-7, SS-8</td>
<td>UL-542 SS-9, CC-8, SS-10</td>
</tr>
<tr>
<td>SAT Test 1</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>SAT Test 2</td>
<td>4</td>
<td>1</td>
<td>0</td>
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<tr>
<td>SAT (Mean)</td>
<td>3.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
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<table>
<thead>
<tr>
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<th>38</th>
<th>39</th>
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</thead>
<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-543 S-10, S-11, S-12</td>
<td>UL-543 S-16, S-17, S-18</td>
<td>UL-544 C-11 70 – 75’</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SAT Test 2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>SAT (Mean)</td>
<td>1.0</td>
<td>1.5</td>
<td>1.0</td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
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</table>

<table>
<thead>
<tr>
<th>Sample No. (given by SINTEF)</th>
<th>40</th>
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<th>42</th>
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<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-544 CC-19 120 – 125’</td>
<td>UL-545 CC-11 85 – 90’</td>
<td>UL-545 CC-10 73 – 78’</td>
</tr>
<tr>
<td>SAT Test 1</td>
<td>14</td>
<td>1</td>
<td>0</td>
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<tr>
<td>SAT Test 2</td>
<td>9</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>SAT (Mean)</td>
<td>11.5</td>
<td>1.0</td>
<td>0.5</td>
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<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>78.6 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>
# Preliminary Test Results - University Link Samples

**Basis:**


**Remark:**

The testing was performed by use of modified SAT steel pieces, allowing testing of soil samples containing particles up to 4 mm. The development and use of modified steel pieces was published in the RETC 2007 proceedings. Percentages of sample material < 4.0 mm and < 1.0 mm are subsequent to the preparation according to the standard procedure for the SAT.

<table>
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<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-540 CC-19, 140 – 145’</td>
<td>UL-511 CC-7, 50 – 55.0’</td>
<td>UL-511 CC-8, 60 – 65’</td>
</tr>
<tr>
<td>SAT Test 1</td>
<td>3</td>
<td>24</td>
<td>9</td>
</tr>
<tr>
<td>SAT Test 2</td>
<td>4</td>
<td>27</td>
<td>11</td>
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<tr>
<td><strong>SAT (Mean)</strong></td>
<td><strong>3.5</strong></td>
<td><strong>25.5</strong></td>
<td><strong>10.0</strong></td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>89.6 %</td>
<td>79.7 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>82.8 %</td>
<td>57.5 %</td>
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<table>
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<tr>
<th>Sample No. (given by SINTEF)</th>
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<th>5</th>
<th>6</th>
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<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-532 CC-10, 99 – 104’</td>
<td>UL-532 CC-9, 80 – 85’</td>
<td>UL-518 CC-17, 205 – 210’</td>
</tr>
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<td>SAT Test 1</td>
<td>4</td>
<td>4</td>
<td>3</td>
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<tr>
<td>SAT Test 2</td>
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<td>2</td>
</tr>
<tr>
<td><strong>SAT (Mean)</strong></td>
<td><strong>3.5</strong></td>
<td><strong>5.0</strong></td>
<td><strong>2.5</strong></td>
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<td>Sample material &lt; 4.0 mm</td>
<td>95.8 %</td>
<td>90.4 %</td>
<td>100 %</td>
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<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>93.5 %</td>
<td>80.4 %</td>
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<th>9</th>
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<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-518 CC-16, 195 – 200’</td>
<td>UL-509 CC-6, 79 – 84’</td>
<td>UL-509 CC-8, 95 – 100’</td>
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<tr>
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<td>26</td>
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<td><strong>2.5</strong></td>
<td><strong>1.5</strong></td>
<td><strong>26.0</strong></td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>99.4 %</td>
<td>100 %</td>
<td>100%</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>98.2 %</td>
<td>100 %</td>
<td>100%</td>
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<td>Sample No. (given by SINTEF)</td>
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<td>36</td>
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<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-543 S-10, S-11, S-12</td>
<td>UL-515 CC-7 80 – 85’</td>
<td>UL-515 CC-6 65 – 70’</td>
</tr>
<tr>
<td>SAT Test 1</td>
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<td>17</td>
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<td>SAT Test 2</td>
<td>2</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td><strong>SAT (Mean)</strong></td>
<td><strong>1.0</strong></td>
<td><strong>17.5</strong></td>
<td><strong>1.0</strong></td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample No. (given by SINTEF)</th>
<th>37</th>
<th>38</th>
<th>39</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-528 CC-33 160 – 165’</td>
<td>UL-528 CC-36 175 – 180’</td>
<td>UL-526 CC-67 310 – 315’</td>
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<tr>
<td>SAT Test 1</td>
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<tr>
<td>SAT Test 2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>SAT (Mean)</strong></td>
<td><strong>2.0</strong></td>
<td><strong>1.0</strong></td>
<td><strong>0.5</strong></td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Sample No. (given by SINTEF)</th>
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<th>41</th>
<th>42</th>
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<tr>
<td>Sample ID. (given by the Client)</td>
<td>UL-526 CC-59 295 – 300’</td>
<td>UL-545 CC-11 85 – 90’</td>
<td>UL-545 CC-10 73 – 78’</td>
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<tr>
<td>SAT Test 1</td>
<td>1</td>
<td>1</td>
<td>0</td>
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<td>SAT Test 2</td>
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<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>SAT (Mean)</strong></td>
<td><strong>1.0</strong></td>
<td><strong>1.0</strong></td>
<td><strong>0.5</strong></td>
</tr>
<tr>
<td>Sample material &lt; 4.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
<tr>
<td>Sample material &lt; 1.0 mm</td>
<td>100 %</td>
<td>100 %</td>
<td>100 %</td>
</tr>
</tbody>
</table>
Soil Abrasion Test (SAT)
UL-546
Wilson Ihrig and Associates.
5776 Broadway
Oakland, California 94618

Compression and Shear Wave Velocity Measurements
Borings UL 546 and UL 551
Puget Sound Transit Consultants, Seattle, WA

This report presents the results of the geophysical measurements in Borings UL 546 and UL 551, Puget Sound Transit Central Link Light Rail, for Puget Sound Transit Consultants, Seattle, Washington. UL 551 is located opposite the University of Washington football Stadium and UL 546 is located in the U of W Stadium parking area. Compression and Shear wave velocities for dynamic soil moduli determinations were measured in the borings on August 15 and 16, 2007.

COMPRESSION AND SHEAR WAVE VELOCITIES

The boring was cased with 2-inch Schedule 40 PVC pipe. The 2-inch casing was backfilled in the borehole annulus with a bentonite/cement grout mixture.

The measured compression and shear wave velocities are presented in the tables attached to this report. The tables show the depths down the bore hole, the field measured interval times, the converted vertical downhole time arrivals, the interval vertical velocities in the boring, and the averaged velocities over the measured intervals. When the velocity boundary does not coincide with a measurement depth, the velocity calculation of that point is not accurate from the preceding point of measurement, and the velocity computation between those two points is not included in the velocity average.
Figures 1 and 2 are the time-depth plots for the borings. The plots are the corrected downhole time arrivals of the measured Compression (P) and Shear (S) wave particle motion, plotted against the depth of measurement. The velocities of the P and S waves are computed from the slopes of the time arrivals on the figures, or as the averaged velocities of the interval velocities. The figures were utilized to determine the depths of the velocity layers in the attached tables and summaries presented below.

The summaries of the measured P and S wave velocities in the borings are as follows:

**Boring UL 546**

<table>
<thead>
<tr>
<th>Depth of Data (feet)</th>
<th>P-wave Velocity (feet/second)</th>
<th>S-wave Velocity (feet/second)</th>
<th>Poisson's Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 11</td>
<td>5026</td>
<td>728</td>
<td>0.4893</td>
</tr>
<tr>
<td>11 to 52</td>
<td>7450</td>
<td>1770</td>
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</tr>
<tr>
<td>52 to 110</td>
<td>7036</td>
<td>1451</td>
<td>0.4778</td>
</tr>
</tbody>
</table>

**Boring UL 551**

<table>
<thead>
<tr>
<th>Depth of Data (feet)</th>
<th>P-wave Velocity (feet/second)</th>
<th>S-wave Velocity (feet/second)</th>
<th>Poisson's Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 20</td>
<td>5971</td>
<td>1245</td>
<td>0.4773</td>
</tr>
<tr>
<td>20 to 60</td>
<td>6915</td>
<td>1560</td>
<td>0.4732</td>
</tr>
<tr>
<td>60 to 140</td>
<td>7613</td>
<td>1745</td>
<td>0.4722</td>
</tr>
</tbody>
</table>

Poisson's Ratio is calculated as follows:

$$\mu = \frac{V_p^2 - 2V_s^2}{2(V_s^2 - V_p^2)}$$

Where:  
$\mu$ = Poisson's Ratio  
$V_p$ = Compression Wave Velocity  
$V_s$ = Shear Wave Velocity

The Compression (P) wave energy was generated by a vertical blow to a metal plate placed on the surface, offset from the casing. The zero time of the hammer blow was determined from an impact switch taped to the hammer. Multiple hammer blows were stacked to enhance the downhole energy arrivals.
The Shear (S) Wave energy source was a 6 by 6-inch plank offset from the casing. The front wheels of a vehicle were placed on the top of the plank to provide coupling with the ground surface. The long direction of the plank was placed tangent to a circle with the radius center at the borehole. An impact switch taped to the handle of the hammer determined zero time.

The source offset from the borehole provides a wave travel path that is in soil that is generally not within the soils adjacent to the borehole, that are disturbed by the drilling operation. The disturbed soil zone may be considered to be relatively constant from the top of the boring to the bottom.

Three detectors, spaced at 10-foot intervals in the borehole, were used to detect the generated S wave energy. To minimize the effect of the detector spiral as they are lowered down the borehole; each detector package contains four sets of horizontal geophones (8 Hz geophones) placed on axes of 45 degrees. The axis of sensitivity of the geophones is 20 degrees.

For the S wave data, two recordings were made at each data point. The two separate recordings were made with reversed (polarized) energy inputs utilizing the opposite ends of the plank (blows right and left). The time arrival of the shear wave energy was determined by comparing arrival times and direction of particle motion of the recorded wave motion in the two data sets.

The particle motion of the shear wave energy is polarized and is dependent on the direction of the energy input. On Blow 1, the particle motion is reversed from that produced by Blow 2. The polarization of the energy helps the interpreter to separate S wave arrivals from other energy arrivals and noise. Reversed particle motion, however, can also occur in other ways such as out-of-phase noise, shear energy generated in the boring annulus backfill and casing as tube waves and P to S conversions. Continuity of the energy arrivals from the surface to the bottom of the hole helps separate these various energy arrivals.

A data sample of the Shear wave data made in Boring UL 546 at a depth of 45 feet is presented below. The vertical cursor is at the point picked as the shear wave arrival time, with the arrival time displayed below the cursor. There are 500 samples across the image, with sample number 240 on the left side of the record (equal to 24 milli-Seconds; each tick mark is 2 ms). The shear wave arrival is shown on Trace 7. Trace 8 is 45 degrees to Trace 7. Trace 5 is 90 degrees to Trace 7. The other reversed energy arrivals are a result of the orientation of the detector package to that of the polarized shear wave and random noise. The detectors will spiral down the casing as they are lowered in the casing so that the orientation of the detector package varies with depth.
The picked arrival times were converted from the "slant distance" travel path to the vertical travel path down the borehole. The "slant distance" travel path is a result of the source to borehole offset. The formula used for the conversion to the 'Corrected Time' vertically down the borehole is:

\[ \text{DH Time} = \text{Record Time} \times [\cos(\arctan (\text{offset/detector depth}))] \]

Borehole drift was not measured in the boring, and no corrections have been applied for possible drift. The velocity changes generally correspond to the logged material changes, so that extreme drift of the borings off of vertical is not expected.

The recording equipment was a Geometrics 1225, a 12-channel signal enhancement digital-recording seismograph. The P wave was measured using a 25-millisecond record length and the S wave was measured with 50 and 100 millisecond record lengths, with various amounts of delay times. The sampling rate was 1000 samples per record length; the samples are an 8 bit word. The data was field recorded on a laptop computer in SEG-1 format. Arrival times were picked from a computer screen image of the records.

The information presented in this report is based upon geophysical measurements made by generally accepted methods and field procedures, and our interpretation of these data. The presented information is based upon our best estimate of subsurface conditions.
considering the geophysical results and all other information available to us. These results are interpretive in nature and are considered to be a reasonably accurate presentation of the existing conditions within the limitations of the method or methods employed.

For Geo-Recon International:

John M. Musser Jr.
Principal Geophysicist
Downhole Compressional and Shear Wave Velocity Measurements

**Borehole: UL-546 - Puget Sound Transit/University Line Light Rail Seattle, Washington**

Shear Wave Data - Interval Velocity Computations

<table>
<thead>
<tr>
<th>Depth of Data</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>9.95</td>
<td>6.770</td>
<td>6.770</td>
<td>------</td>
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**Velocity Change at ~ 11 feet**

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<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
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</thead>
<tbody>
<tr>
<td>15.0</td>
<td>18.60</td>
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<td>3.215</td>
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**Velocity Change at ~ 52 feet**

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<th>Interval Time</th>
<th>Interval Velocity</th>
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Source to Borehole offset: 7 feet. Velocities in feet per second.
Casing pickup above ground: 0 feet. Depths in feet - Times in milli-seconds.
n/a - Not included in Velocity Average. Velocity breaks from Time-Depth Plot.
Elevation Difference between Source and Top of Casing: 0 ft
Downhole Compressional and Shear Wave Velocity Measurements

Borehole: UL-546 - Puget Sound Transit/University LLink Light Rail
Seattle, Washington

Compressional Wave Data - Interval Velocity Computations

<table>
<thead>
<tr>
<th>Depth of Data</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
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Velocity Change at ~ 11 feet

<p>| | | | | | |</p>
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Velocity Change at ~ 52 feet

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Source to Borehole offset: 3.5 feet.  Velocities in feet per second.
Casing stickup above ground: 0 feet.  Depths in feet - Times in milli-seconds.
n/a - Not included in Velocity Average.  Velocity Breaks from Time-Depth Plot.
Elevation Difference between Source and Top of Casing: 0 ft

P Wave UL-546
UL-546 - Puget Sound Transit/University Light Rail
Compression and Shear Wave Velocities

- Shear Wave Arrivals
- Compressional Wave Arrival

Figure 1
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Date</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/1/07</td>
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<td></td>
<td></td>
<td></td>
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</table>
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Monitoring Well UL-546W</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>59.7</td>
<td>--</td>
<td>8.7</td>
<td>18.7</td>
<td>29.28 07/06/07 13:25</td>
<td>28.07 07/08/08 12:40</td>
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</tbody>
</table>
### Water Levels on Hydrograph

- **Ground Surface Elevation (ft):** 59.7
- **VWP Elevation (ft):** 13.2
- **Screen Int. Top Elev. (ft):** --
- **Screen Int. Bottom Elev. (ft):** --
- **Maximum Water Level Elevation (ft):** 30.10 (12/05/07 15:33)
- **Minimum Water Level Elevation (ft):** 26.64 (07/08/08 10:01)

---

**VWP (Slope Indicator)**

**Geotechnical Data Report**

**Groundwater Data**

Sound Transit University Link Explorations // Seattle, WA
Particle Size Distribution Report

- **Cobbles**: 0.0
- **% GRAVEL**: 20.8
- **% SAND**: 36.5
- **% SILT**: 42.7
- **% CLAY**:
- **USCS**: SM
- **AASHTO**: A-4(0)
- **PL**: NP
- **LL**: NV

**SIEVE**

<table>
<thead>
<tr>
<th>SIEVE inches size</th>
<th>PERCENT FINER</th>
<th>SIEVE number size</th>
<th>PERCENT FINER</th>
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</thead>
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<td>#4</td>
<td>79.2</td>
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<tr>
<td>.75</td>
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<td>#10</td>
<td>74.9</td>
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<td>.5</td>
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<td>#20</td>
<td>72.3</td>
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<td>#40</td>
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<td>#60</td>
<td>61.6</td>
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<td></td>
<td>#140</td>
<td>48.6</td>
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<tr>
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<td>#200</td>
<td>42.7</td>
</tr>
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</table>

**GRAIN SIZE - MM**

- **D_60**: 0.2250
- **D_30**:
- **D_10**:
- **C_c**
- **C_u**

**REMARKS**

- **USC Classification**: ∘ silty sand with gravel
- **Classification based on grainsize only**

**Source of Sample**: UL-546  Depth: 25.0-25.8  Sample Number: SS-3

**SOIL TECHNOLOGY**

**Bainbridge Island, WA**

**Client**: Sound Transit  **Project**: University Link Project RTA/LR 8-06

**Tested By**: AJA  **Checked By**: RGS
**Atterberg Limits Test Report (ASTM D-4318)**

Dashed line indicates the approximate upper limit boundary for natural soils.

---

**SOIL DATA**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
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<tr>
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<td>UL-546</td>
<td>SS-4</td>
<td>45.0-45.75</td>
<td>21.1</td>
<td>15</td>
<td>21</td>
<td>6</td>
<td>CL-ML</td>
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<tr>
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<td>65.0-66.5</td>
<td>25.0</td>
<td>21</td>
<td>54</td>
<td>33</td>
<td>CH</td>
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<tr>
<td>▲</td>
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<td>SS-8</td>
<td>85.0-86.5</td>
<td>27.3</td>
<td>23</td>
<td>52</td>
<td>29</td>
<td>CH</td>
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<tr>
<td>●</td>
<td>UL-546</td>
<td>SS-10</td>
<td>105.0-106.5</td>
<td>21.9</td>
<td>23</td>
<td>39</td>
<td>16</td>
<td>CL</td>
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</tbody>
</table>

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**SOIL TECHNOLOGY**

Bainbridge Island, WA

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

Tested By: JO JO AJA AJA Checked By: RGS

Figure 42
UL-547A
PRESSUREMETER DATA
Link Light Rail Project University Link
Hole No. UL 547 Depth 29.5 ft File C:\DATA\C-326\ST31.P

Pressure
Shear Modulus 63194 psi
Shear Modulus 45959 psi

Radial Displacement / Radius(%)
File C:\DATA\C-326\ST31.P

Shear Strength  236.3 psi
Limit Pressure   1079 psi

HUGHES
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-13-07
Hole No. UL 547 Depth 29.5 ft File C:\DATA\C-326\ST31.P

HUGHES
GIBSON'S CLAY MODEL
Shear Strength 120 psi
Insitu Stress 20 psi
Shear Modulus 50000 psi

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

Pressure (psi)
0 250 500 750 1000
0 2 4 6 8
Radial Displacement / Radius(%) (Shear Strain/2)
PRESSUREMETER DATA
Link Light Rail Project University Link
Hole No. UL 547 Depth 29.5 ft
File C:\DATA\C-326\ST31.P

THE HUGHES SAND MODEL
- Water Pressure: 10 psi
- Friction Angle: 40 deg
- Critical Friction Angle: 32 deg
- Lateral Stress: 30 psi
- Shear Modulus: 50000 psi

Field Data
- Sand Model Curve

Radial Displacement / Radius (%)

Pressure (psi)
Hole No. UL 547  Depth 29.5ft  

Field Data

Slope of Log Normal Data

Shear Strength 43.8 psi  
Limit Pressure 588 psi
PRESSUREMETER DATA

North Transit Partners
Link Light Rail Project University Link 6-13-07
Hole No. UL 547 Depth 29.5ft File C:\DATA\C-326\ST31U.P

GIBSON'S CLAY MODEL
Shear Strength 110 psi
Insitu Stress 0 psi
Shear Modulus 60000 psi

Field Data
Clay Model Curve
Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)
Pressure (psi)
HUGHES

Shear Modulus 123856 psi
Shear Modulus 88888 psi
Shear Modulus  13247 psi
Shear Modulus  88888 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-13-07
Hole No. UL-547 Depth 28ft
File C:\DATA\C-326\ST32.P

Shear Strength 352.3 psi
Limit Pressure 1956 psi
**PRESSUREMETER DATA**

North Transit Partners

Link Light Rail Project University Link 6-13-07

Hole No. UL-547 Depth 28ft File C:\DATA\C-326\ST32.P

---

**GIBSON'S CLAY MODEL**

Shear Strength 250 psi
Insitu Stress 100 psi
Shear Modulus 60000 psi

---

**Field Data**

- **Clay Model Curve**
- **Undrained Stress Strain Curve**
Shear Strength 354 psi
Limit Pressure 1997 psi
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-13-07

Hole No. UL 547 Depth 28ft File C:\DATA\C-326\ST32U.P

Shear Strength 300 psi
Insitu Stress 0 psi
Shear Modulus 60000 psi

shift 5.2

GIBSON'S CLAY MODEL

Field Data
Clay Model Curve
Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)
Hole No. UL-547  Depth 68.2ft

Shear Modulus 9254 psi
Shear Modulus 1654 psi

Radial Displacement / Radius(%)

Pressure (psi)
Hole No. UL-547  Depth 68.2ft  File C:\DATA\C-326\ST35.P

Pressure

Field Data
Shear Modulus

Shear Modulus 10912 psi
Shear Modulus 9254 psi

Radial Displacement / Radius(%)
**PRESSUREMETER DATA**

North Transit Partners

Link Light Rail Project University Link 06/14/07

Hole No. UL-547 Depth 68.2ft File C:\DATA\C-326\ST35.P

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<th>Pressure (psi)</th>
<th>Log Radial Displacement / Radius(%)</th>
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<td>300</td>
<td>4</td>
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<tr>
<td>400</td>
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</table>

- **Field Data**
- **Slope of Log Normal Data**

**Shear Strength** 98.1 psi
**Limit Pressure** 420 psi

HUGHES
The Hughes Sand Model

Water Pressure: 10 psi
Friction Angle: 40 deg
Critical Friction Angle: 32 deg
Lateral Stress: 20 psi
Shear Modulus: 8000 psi

Field Data vs. Sand Model Curve

Pressure (psi) vs. Radial Displacement / Radius (%)

Hole No. UL-547, Depth 68.2ft
File C:\DATA\C-326\ST35.P

North Transit Partners
Link Light Rail Project University Link
06/14/07
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link 06/14/07
Hole No. UL 547 Depth 68.2 ft File C:\DATA\C-326\ST35U.P

Shear Strength 40 psi
Limit Pressure 342 psi

HUGHES
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link
6-15-07

Hole No. UL 547 Depth 111ft File C:\DATA\C-326\ST38.P

Field Data
- Shear Modulus

Shear Modulus 7134 psi
Shear Modulus 5410 psi
Hole No. UL 547 Depth 111ft

Shear Strength 89.5 psi
Limit Pressure 671 psi
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-15-07

Hole No. UL 547 Depth 111ft File C:\DATA\C-326\ST38.P

---

GIBSON'S CLAY MODEL

Shear Strength 90 psi
In-situ Stress 200 psi
Shear Modulus 10000 psi

---

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

---

Radial Displacement / Radius(%) (Shear Strain/2)
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 547 Depth 111ft
6-15-07
File C:\DATA\C-326\ST38U.P

Shear Strength 101.9 psi
Limit Pressure 550 psi
GIBSON'S CLAY MODEL

Shear Strength 90 psi
Insitu Stress 0 psi
Shear Modulus 12000 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-15-07
Hole No. UL-547 Depth 109.5ft File C:\DATA\C-326\ST39.P

Shear Modulus
- Field Data
- Shear Modulus

Shear Modulus 3666 psi
Shear Modulus 3304 psi

Radial Displacement / Radius(%)
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link
6-15-07
Hole No. UL-547 Depth 109.5ft
File C:\DATA\C-326\ST39.P

- Shear Strength 75.6 psi
- Limit Pressure 518 psi
Hole No. UL-547, Depth 109.5ft

GIBSON'S CLAY MODEL

- Shear Strength: 60 psi
- In-situ Stress: 200 psi
- Shear Modulus: 6000 psi

Field Data
- Clay Model Curve
- Undrained Stress-Strain Curve
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-15-07
Hole No. UL 547 Depth 109.5ft File C:\DATA\C-326\ST39U.P

Shear Strength 94.5 psi
Limit Pressure 488 psi

Field Data
Slope of Log Normal Data

Log Radial Displacement / Radius (%)

Pressure (psi)

0 250 500 750 1000
1 2 3 4 5 6 7 8 9 10

shift-.5

Hughes
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-15-07
Hole No. UL 547 Depth 109.5ft File C:\DATA\C-326\ST39U.P

HUGHES GIBSON'S CLAY MODEL
Shear Strength 90 psi
In situ Stress 0 psi
Shear Modulus 8000 psi

Pressure (psi)
0 250 500 750 1000
0 2 4 6 8
Radial Displacement / Radius(%) (Shear Strain/2)
shift - 0.5
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Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Date</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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</thead>
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<td>12/30/07</td>
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<tr>
<td>3/9/08</td>
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<td>6/1/08</td>
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</table>

VWP (Slope Indicator)
### Soil Technology

**Bainbridge Island, WA**

**Client:** Sound Transit  
**Project:** University Link Project RTA/LR 8-06  
**Project No.:** J-07-2195  
**Figure:** 22

**Tested By:** RMD  
**Checked By:** RGS

---

#### Particle Size Distribution Report

**Classification based on grain size only**

<table>
<thead>
<tr>
<th><strong>GRAIN SIZE - MM</strong></th>
<th><strong>PERCENT FINER</strong></th>
<th><strong>PERCENT COARSER</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1/2 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1/4 in.</td>
<td>-</td>
<td>-</td>
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<tr>
<td>1/8 in.</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1/16 in.</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

**USC Classification**

- **SILTY SAND WITH GRAVEL**
  - USCS: SM
  - AASHTO: A-2-4(0)
  - PL: NP
  - LL: NV

**Remarks:**

- Classification based on grain size only
- Classification based on grain size only

---

#### Particle Size Distribution Report

**Cobbles**

- % GRAVEL 18.3
- % SAND 47.4
- % SILT 34.3

**USC Classification**

- **SILTY SAND WITH GRAVEL**
  - USCS: SM
  - AASHTO: A-2-4(0)
  - PL: NP
  - LL: NV

**Remarks:**

- Classification based on grain size only
- Classification based on grain size only

---

#### Particle Size Distribution Report

**Sieve Number**

<table>
<thead>
<tr>
<th><strong>Sieve size</strong></th>
<th><strong>Percent finer</strong></th>
<th><strong>Percent coarser</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>100.0</td>
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<td>1</td>
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<td>92.2</td>
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<tr>
<td>.75</td>
<td>91.2</td>
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<tr>
<td>.375</td>
<td>85.7</td>
<td>83.5</td>
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</table>

**Source of Sample:** UL-547  
**Depth:** 30.0-31.0  
**Sample Number:** CC-3

---

#### Particle Size Distribution Report

**Sieve Number**

<table>
<thead>
<tr>
<th><strong>Sieve size</strong></th>
<th><strong>Percent finer</strong></th>
<th><strong>Percent coarser</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>81.7</td>
<td>79.4</td>
</tr>
<tr>
<td>#10</td>
<td>77.9</td>
<td>74.6</td>
</tr>
<tr>
<td>#20</td>
<td>74.3</td>
<td>69.7</td>
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<tr>
<td>#40</td>
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<td>#60</td>
<td>56.7</td>
<td>42.4</td>
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<tr>
<td>#140</td>
<td>39.2</td>
<td>21.1</td>
</tr>
<tr>
<td>#200</td>
<td>34.3</td>
<td>18.2</td>
</tr>
</tbody>
</table>

**Source of Sample:** UL-547  
**Depth:** 80.0-81.0  
**Sample Number:** CC-7

---

#### Particle Size Distribution Report

**Coefficient Calculation**

- **Cc**
- **Cu**
### Atterberg Limits Test Report (ASTM D-4318)

Dashed line indicates the approximate upper limit boundary for natural soils.

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UL-547</td>
<td>CC-5</td>
<td>52.0-53.0</td>
<td>16.8</td>
<td>18</td>
<td>32</td>
<td>14</td>
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<tr>
<td></td>
<td>UL-547</td>
<td>CC-8</td>
<td>93.0-94.0</td>
<td>30.9</td>
<td>24</td>
<td>45</td>
<td>21</td>
<td>CL</td>
</tr>
<tr>
<td></td>
<td>UL-547</td>
<td>CC-9</td>
<td>108.0-109.0</td>
<td>22.1</td>
<td>20</td>
<td>48</td>
<td>28</td>
<td>CL</td>
</tr>
</tbody>
</table>

### SOIL TECHNOLOGY

Bainbridge Island, WA

Client: Sound Transit  
Project: University Link Project RTA/LR 8-06  
Project No.: J-07-2195  
Figure 43

Tested By: AJA  
Checked By: RGS
UL-547B
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Monitoring Well</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL-547BW</td>
<td>63.3</td>
<td>--</td>
<td>18.3</td>
<td>28.3</td>
<td>30.25</td>
<td>29.41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>07/06/07 13:01</td>
<td>07/08/08 13:15</td>
</tr>
</tbody>
</table>
### Daily Average Water Level Elevations (ft)

<table>
<thead>
<tr>
<th>Date</th>
<th>Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/6/07</td>
<td>23</td>
</tr>
<tr>
<td>12/11/07</td>
<td>26.7</td>
</tr>
<tr>
<td>6/19/08</td>
<td>33.8</td>
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<td>24.2</td>
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<td>25.4</td>
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<tr>
<td>1/17/08</td>
<td>27.8</td>
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<tr>
<td>1/31/08</td>
<td>29</td>
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<td>2/14/08</td>
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<td>31.4</td>
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<tr>
<td>7/3/08</td>
<td></td>
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<tr>
<td>7/1/08</td>
<td></td>
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</tbody>
</table>

**Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.**

- **Ground Surface Elevation (ft):** 63.3
- **VWP Elevation (ft):** 26.7
- **Screen Int. Top Elev. (ft):** --
- **Screen Int. Bottom Elev. (ft):** --
- **Maximum Water Level Elevation (ft):** 30.59 (12/11/07 00:00)
- **Minimum Water Level Elevation (ft):** 28.09 (07/08/08 10:01)

**UL-547BWx**

**VWP (Slope Indicator)**
UL-548
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-19-07
Hole No. UL 548 Depth 29ft File C:\DATA\C-326\ST41.P

Field Data

Shear Modulus 10444 psi
Shear Modulus 246296 psi

shift 0

Hughes
Hole No. UL 548  Depth 29ft  File C:\DATA\C-326\ST41.P

Pressure

1000

750

500

250

0

Radial Displacement / Radius(%) 0  3  6  9  12

Field Data

Shear Modulus 246296 psi

Shear Modulus 7777 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-19-07
Hole No. UL 548 Depth 29ft File C:\DATA\C-326\ST41.P

Shear Strength 364.9 psi
Limit Pressure 1487 psi
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link

Hole No. UL 548 Depth 29ft File C:\DATA\C-326\ST41.P

HUGHES

GIBSON’S CLAY MODEL

Shear Strength 250 psi
Insitu Stress 100 psi
Shear Modulus 15000 psi

Field Data
Clay Model Curve
Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)
PRESSUREMETER DATA  
North Transit Partners  
Link Light Rail Project University Link  
6-19-07  
Hole No. UL 548  
Depth 29ft  
File C:\DATA\C-326\ST41.P

THE HUGHES SAND MODEL

- Water Pressure  15 psi
- Friction Angle  40 deg
- Critical Friction Angle  32 deg
- Lateral Stress  20 psi
- Shear Modulus  100000 psi

Field Data

Sand Model Curve

Pressure (psi)

Radial Displacement / Radius(%)
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-19-07
Hole No. UL 548 Depth 29ft File C:\DATA\C-326\ST41U.P

Shear Strength 87.7 psi
Limit Pressure 1076 psi
Hole No. UL 548 Depth 29ft File C:\DATA\C-326\ST41U.P

GIBSON'S CLAY MODEL
Shear Strength 220 psi
Insitu Stress 0 psi
Shear Modulus 120000 psi

Radial Displacement / Radius(%) (Shear Strain/2)

shift 4.7
Hole No. UL 548  Depth 59ft  File C:\DATA\C-326\ST43.P

Field Data

Shear Modulus 91111 psi
Shear Modulus 7333 psi
HUGHES

Shear Modulus  7333 psi

Shear Modulus  8682 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
File C:\DATA\C-326\ST43.P
Hole No. UL 548 Depth 59ft

Shear Strength 539.5 psi
Limit Pressure 1923 psi

Hughes
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-19-07
Hole No. UL 548 Depth 59ft File C:\DATA\C-326\ST43.P

0

Field Data
Clay Model Curve
Undrained Stress Strain Curve

GIBSON'S CLAY MODEL

Shear Strength 320 psi
Insitu Stress 100 psi
Shear Modulus 15000 psi

Radial Displacement / Radius(%) (Shear Strain/2) shift 0

HUGHES

Pressure (psi)

1200

900

600

300

0

0  3  6  9  12

HUGHES
**THE HUGHES SAND MODEL**

- Water Pressure: 30 psi
- Friction Angle: 40 deg
- Critical Friction Angle: 32 deg
- Lateral Stress: 30 psi
- Shear Modulus: 90000 psi

**PRESSUREMETER DATA**

North Transit Partners

Link Light Rail Project University Link 6-19-07

Hole No. UL 548 Depth 59ft File C:\DATA\C-326\ST43.P

---

**Graph Details**

- **Pressure (psi)**: 0 to 1200
- **Radial Displacement / Radius(%)**: 0 to 12

---

**Line Descriptions**

- **Field Data**
- **Sand Model Curve**
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link 6-19-07
Hole No. UL 548 Depth 59ft File C:\DATA\C-326\ST43U.P

Field Data
Slope of Log Normal Data

Pressure (psi)

Shear Strength 283.6 psi
Limit Pressure 1758 psi

shift 1.2

HUGHES
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link 6-19-07
Hole No. UL 548 Depth 59ft File C:\DATA\C-326\ST43U.P

HUGHES
GIBSON'S CLAY MODEL
Shear Strength 280 psi
Insitu Stress 0 psi
Shear Modulus 60000 psi

Field Data
Clay Model Curve
Undrained Stress Strain Curve

Pressure (psi)

Radial Displacement / Radius(%) (Shear Strain/2)
Hole No. UL 548  Depth 79.5ft  File C:\DATA\C-326\ST44.P

Shear Modulus 4074 psi

Shear Modulus 4706 psi

Radial Displacement / Radius(%)

shift 0

Hughes
Shear Modulus 428 psi

Shear Modulus 4074 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 548 Depth 79.5ft
6-20-07
File C:\DATA\C-326\ST44.P

Field Data
Slope of Log Normal Data

Shear Strength 23.2 psi
Limit Pressure 156 psi
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link 6-20-07
Hole No. UL 548 Depth 79.5ft File C:\DATA\C-326\ST44.P

GIBSON'S CLAY MODEL

Shear Strength 20 psi
In situ Stress 40 psi
Shear Modulus 4000 psi

Field Data
• Clay Model Curve
• Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)

HUGHES
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link 6-20-07
Hole No. UL 548 Depth 79.5ft File C:\DATA\C-326\ST44.P

THE HUGHES SAND MODEL
Water Pressure  20  psi
Friction Angle  32  deg
Critical Friction Angle  32  deg
Lateral Stress  15  psi
Shear Modulus  4000 psi

Field Data
- Sand Model Curve

Radial Displacement / Radius(%)
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 548
Depth 79.5 ft

File C:\DATA\C-326\ST44U.P

Shear Strength 7 psi
Limit Pressure 109 psi
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-20-07

Hole No. UL 548 Depth 79.5ft File C:\DATA\C-326\ST44U.P

GIBSON'S CLAY MODEL

Shear Strength 24 psi
Insitu Stress 0 psi
Shear Modulus 12000 psi

Radial Displacement / Radius(%) (Shear Strain/2)

Pressure (psi)

Field Data
Clay Model Curve
Undrained Stress Strain Curve

HUGHES
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Date</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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</thead>
<tbody>
<tr>
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<td>-9.4</td>
<td>0.6</td>
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<td></td>
<td></td>
<td>11/20/07 10:35</td>
<td>07/01/08 11:17</td>
</tr>
</tbody>
</table>
Particle Size Distribution Report

Cobbles | % GRAVEL | % SAND | % SILT | % CLAY | USCS | AASHTO | PL | LL
---|---|---|---|---|---|---|---|---
0.0 | 7.3 | 60.8 | | 31.9 | SM | A-2-4(0) | NP | NV

SIEVE PERCENT FINER

<table>
<thead>
<tr>
<th>SIEVE</th>
<th>PERCENT FINER</th>
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</thead>
<tbody>
<tr>
<td>.75</td>
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<td>.5</td>
<td>98.3</td>
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<tr>
<td>.375</td>
<td>96.3</td>
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</tbody>
</table>

SIEVE PERCENT FINER

<table>
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<tr>
<th>SIEVE</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
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<td>#4</td>
<td>92.7</td>
</tr>
<tr>
<td>#10</td>
<td>88.8</td>
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<tr>
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<td>83.5</td>
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<td>73.4</td>
</tr>
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<td>#60</td>
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<tr>
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<td>36.0</td>
</tr>
<tr>
<td>#200</td>
<td>31.9</td>
</tr>
</tbody>
</table>

USC Classification

- silty sand

REMARKS:

- Classification based on grainsize only

GRAIN SIZE - MM

- 0.001
- 0.01
- 0.1
- 1
- 10
- 100

PERCENT FINER

- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 0

PERCENT COARSER

- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 0

PERCENT COARSER

- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 0

PERCENT FINER

- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 0

Source of Sample: UL-548  Depth: 40.0-41.0  Sample Number: CC-4

SOIL TECHNOLOGY

Bainbridge Island, WA

Client:  Sound Transit
Project:  University Link Project RTA/LR 8-06
Project No.:  J-07-2195

Tested By:  AJA  Checked By:  RGS
### Atterberg Limits Test Report (ASTM D-4318)

Dashed line indicates the approximate upper limit boundary for natural soils.

### SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
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<tbody>
<tr>
<td>●</td>
<td>UL-548</td>
<td>CC-7</td>
<td>78.0-79.0</td>
<td>17.2</td>
<td>NP</td>
<td>GNP</td>
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<td>CC-9</td>
<td>100.0-101.0</td>
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<td>CC-9</td>
<td>108.0-109.0</td>
<td>22.1</td>
<td>20</td>
<td>48</td>
<td>28</td>
<td>CL</td>
</tr>
</tbody>
</table>

NP/GNP = Granular Non-Plastic

### SOIL TECHNOLOGY

Bainbridge Island, WA

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

Tested By: JO  Checked By: RGS
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link

Hole No. UL 549 Depth 19ft

File C:\DATA\C-326\ST40.P

Field Data

Shear Modulus 16501 psi

Shear Modulus 11944 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
6-19-07
Hole No. UL 549 Depth 19ft File C:\DATA\C-326\ST40.P

Field Data
Shear Modulus

Shear Modulus 1928 psi
Shear Modulus 11944 psi

Pressure (psi)
Radial Displacement / Radius(%)
### PRESSUREMETER DATA

**North Transit Partners**

- **Link Light Rail Project University Link**
- **Hole No. UL 549**
- **Depth 19ft**
- **File C:\DATA\C-326\ST40.P**

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
<th>Log Radial Displacement / Radius(%)</th>
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<tr>
<td>100</td>
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<td>200</td>
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</tr>
<tr>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>400</td>
<td>4</td>
</tr>
</tbody>
</table>

- **Field Data**
- **Slope of Log Normal Data**

**Shear Strength**: 94.5 psi
**Limit Pressure**: 416 psi

Signature: **Hughes**

**Shift 3**
GIBSON'S CLAY MODEL

Shear Strength 60 psi
Insitu Stress 40 psi
Shear Modulus 6000 psi

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

Pressure (psi)

Radial Displacement / Radius(%) (Shear Strain/2)
### PRESSUREMETER DATA

**North Transit Partners**

**Link Light Rail Project University Link**

Hole No. UL 549  
Depth 19ft  
File C:\DATA\C-326\ST40.P  

**THE HUGHES SAND MODEL**

- **Water Pressure**: 10 psi
- **Friction Angle**: 40 deg
- **Critical Friction Angle**: 32 deg
- **Lateral Stress**: 20 psi
- **Shear Modulus**: 8000 psi

---

**Graph Details**

- **Axes**:
  - **X-axis**: Radial Displacement / Radius (%)
  - **Y-axis**: Pressure (psi)

- **Graph Lines**:
  - Red: Field Data
  - Blue: Sand Model Curve

---

**Shift 3**

**Hughes**
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-19-07
Hole No. UL 549 Depth 19ft
File C:\DATA\C-326\ST40U.P

Shear Strength 17.6 psi
Limit Pressure 254 psi

Field Data
Slope of Log Normal Data

Pressure (psi)

Log Radial Displacement / Radius(%)
Hole No. UL 549  Depth 19ft

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

GIBSON'S CLAY MODEL

Shear Strength 50 psi
In situ Stress 0 psi
Shear Modulus 40000 psi

Radial Displacement / Radius(%) (Shear Strain/2)
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link

6-19-07

Hole No. UL 549 Depth 38.5ft File C:\DATA\C-326\ST42.P

Pressure (psi)

Field Data

Shear Modulus

Shear Modulus 9937 psi

Shear Modulus 156349 psi

Radial Displacement / Radius(%)
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link  6-19-07
Hole No.  UL 549  Depth 38.5ft  File C:\DATA\C-326\ST42.P

Field Data
Shear Modulus  156349  psi
Shear Modulus  308730  psi

Pressure (psi)

Radial Displacement / Radius(%)
Hole No. UL 549  Depth 38.5ft

Pressure (psi)

Log Radial Displacement / Radius(%)
Field Data
Clay Model Curve
Undrained Stress Strain Curve

GIBSON'S CLAY MODEL
Shear Strength 320 psi
Insitu Stress 100 psi
Shear Modulus 15000 psi

Radial Displacement / Radius(%) (Shear Strain/2)
Hole No. UL 549  Depth 38.5ft  File C:\DATA\C-326\ST42U.P

Shear Strength  148.9 psi
Limit Pressure  1448 psi

shift 5.8

HUGHES
PRESSUREMETER DATA

Link Light Rail Project University Link
Hole No. UL 549
Depth 38.5ft

File C:\DATA\C-326\ST42U.P

GIBSON'S CLAY MODEL

Shear Strength 280 psi
In situ Stress 0 psi
Shear Modulus 120000 psi

shift 5.8

HUGHES
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-20-07
Hole No. UL 549 Depth 58ft File C:\DATA\C-326\ST47.P

Field Data

Shear Modulus 63194 psi
Shear Modulus 52564 psi

HUGHES
Hole No. UL 549    Depth 58ft    File C:\DATA\C-326\ST47.P

Shear Modulus  4136 psi
Shear Modulus  52564 psi
Shear Strength 305.8 psi
Limit Pressure 1401 psi
Hole No. UL 549  Depth 58ft  File C:\DATA\C-326\ST47.P

**GIBSON'S CLAY MODEL**

- Shear Strength 230 psi
- Insitu Stress 40 psi
- Shear Modulus 30000 psi

**Pressure Data**

- Field Data
- Clay Model Curve
- Undrained Stress Strain Curve
The Hughes Sand Model

- Water Pressure: 20 psi
- Friction Angle: 42 deg
- Critical Friction Angle: 32 deg
- Lateral Stress: 30 psi
- Shear Modulus: 50000 psi

Field Data
- Sand Model Curve

Pressure (psi)

Radial Displacement / Radius(%)
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-20-07
Hole No. UL 549 Depth 58ft File C:\DATA\C-326\ST47U.P

Shear Strength 283.6 psi
Limit Pressure 1698 psi

Field Data
Slope of Log Normal Data

Log Radial Displacement / Radius(%)
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-20-07
Hole No. UL 549 Depth 58ft File C:\DATA\C-326\ST47U.P

HUGHES

GIBSON'S CLAY MODEL

Shear Strength 300 psi
In situ Stress 0 psi
Shear Modulus 40000 psi

Field Data
Clay Model Curve
Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)
 PRESSUREMETER DATA North Transit Partners
Link Light Rail Project University Link 6-21-07
Hole No. UL 549 Depth 86ft File C:\DATA\C-326\ST48.P

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
<th>Radial Displacement / Radius(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>200</td>
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<tr>
<td>600</td>
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<tr>
<td>800</td>
<td>0</td>
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</table>

- Field Data
- Shear Modulus

Shear Modulus 7949 psi
Shear Modulus 5977 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 549 Depth 86ft
File C:\DATA\C-326\ST48.P

Shear Strength 114.7 psi
Limit Pressure 580 psi

HUGHES
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link
6-21-07

Hole No. UL 549 Depth 86ft File C:\DATA\C-326\ST48.P

---

GIBSON'S CLAY MODEL

Shear Strength 100 psi
Insitu Stress 40 psi
Shear Modulus 6000 psi

---

Field Data
Clay Model Curve
Undrained Stress Strain Curve
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-21-07

Hole No. UL 549 Depth 86ft

File C:\DATA\C-326\ST48U.P

Shear Strength 121.3 psi
Limit Pressure 593 psi

Field Data
Slope of Log Normal Data

Log Radial Displacement / Radius(%)
**PRESSUREMETER DATA**  
North Transit Partners  
Link Light Rail Project University Link  
Hole No. UL 549  
Depth 86ft  
File C:\DATA\C-326\ST48U.P

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
<th>Radial Displacement / Radius(%) (Shear Strain/2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
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<td>0</td>
<td>4</td>
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<tr>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>0</td>
<td>8</td>
</tr>
</tbody>
</table>

**GIBSON’S CLAY MODEL**

- **Shear Strength**: 115 psi
- **In situ Stress**: 0 psi
- **Shear Modulus**: 8000 psi

---

**HUGHES**
Hole No. UL 549  Depth 84.5ft  File C:\DATA\C-326\ST49.P

Shear Modulus  6765 psi
Shear Modulus  7330 psi

shift 0
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-21-07

Hole No. UL 549 Depth 84.5ft File C:\DATA\226\ST49.P

Field Data

Shear Modulus 4712 psi

Shear Modulus 7353 psi
Hole No. UL 549  Depth 84.5ft  File C:\DATA\C-326\ST49.P

PRESSUREMETER DATA  North Transit Partners
Link Light Rail Project University Link  6-21-07

Shear Strength 94.3 psi
Limit Pressure 548 psi

Field Data
Slope of Log Normal Data

Log Radial Displacement / Radius(%)
Hole No. UL 549  
Depth 84.5ft

GIBSON'S CLAY MODEL

- Shear Strength 100 psi
- In-situ Stress 50 psi
- Shear Modulus 7000 psi

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve
Hole No. UL 549    Depth 84.5 ft

Shear Strength 116.5 psi
Limit Pressure 626 psi
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-21-07

Hole No. UL 549 Depth 84.5ft File C:\DATA\C-326\ST49U.P

HUGHES

GIBSON'S CLAY MODEL

Shear Strength 115 psi
Insitu Stress 0 psi
Shear Modulus 12000 psi

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

Pressure (psi)

Radial Displacement / Radius(%) (Shear Strain/2)

shift .7

HUGHES
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link  6-21-07
Hole No. UL 549    Depth 106ft    File C:\DATA\C-326\ST50.P

Pressure

Field Data
Shear Modulus

Shear Modulus  7949 psi
Shear Modulus  7330 psi

Radial Displacement / Radius(%)
PRESSUREMETER DATA  North Transit Partners
Link Light Rail Project University Link  6-21-07
Hole No.  UL 549  Depth 106ft  File C:\DATA\C-326\ST50.P

Field Data
Shear Modulus   7330  psi
Shear Modulus   4057  psi

Pressure (psi)

Radial Displacement / Radius(%)
GIBSON'S CLAY MODEL

Shear Strength 110 psi
Insuitu Stress 70 psi
Shear Modulus 8000 psi

Radial Displacement / Radius(%) (Shear Strain/2)

Field Data
Clay Model Curve
Undrained Stress Strain Curve

HUGHES
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link
6-21-07
Hole No. UL 549 Depth 106ft
File C:\DATA\C-326\ST50.P

Field Data

Slope of Log Normal Data

Shear Strength 104.3 psi
Limit Pressure 625 psi

HUGHES
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
6-21-07
Hole No. UL 549 Depth 106ft
File C:\DATA\C-326\ST50U.P

Field Data
Slope of Log Normal Data

- Shear Strength 126.2 psi
- Limit Pressure 658 psi

shift 1.3
PRESSUREMETER DATA  North Transit Partners
Link Light Rail Project University Link  6-21-07
Hole No.  UL 549  Depth 106ft  File C:\DATA\C-326\ST50U.P

GIBSON'S CLAY MODEL
Shear Strength  130  psi
Insitu Stress  0  psi
Shear Modulus  12000  psi

Radial Displacement / Radius(%) (Shear Strain/2)

Field Data
Clay Model Curve
Undrained Stress Strain Curve
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 6-21-07

Hole No. UL 549 Depth 104.5ft File C:\DATA\C-326\ST51.P

Field Data

- Shear Modulus 7528 psi
- Shear Modulus 7725 psi

shift 0
PRESSUREMETER DATA  North Transit Partners
Link Light Rail Project University Link 6-21-07
Hole No. UL 549  Depth 104.5ft  File C:\DATA\C-326\ST51.P

Field Data
Shear Modulus  4722 psi
Shear Modulus  7725 psi

Pressure (psi)

Radial Displacement / Radius(%)
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-21-07
Hole No. UL 549 Depth 104.5ft File C:\DATA\C-326\ST51.P

Field Data
Slope of Log Normal Data

Shear Strength 137.1 psi
Limit Pressure 666 psi

Shift 2
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-21-07
Hole No. UL 549 Depth 104.5ft File C:\DATA\C-326\ST51.P

GIBSON'S CLAY MODEL
Shear Strength 110 psi
Insitu Stress 70 psi
Shear Modulus 8000 psi

Field Data
Clay Model Curve
Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 6-21-07
Hole No. UL 549 Depth 104.5ft File C:\DATA\C-326\ST51U.P

Shear Strength 131.3 psi
Limit Pressure 664 psi
Hole No. UL 549 Depth 104.5ft File C:\DATA\C-326\ST51U.P

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

GIBSON'S CLAY MODEL
Shear Strength 130 psi
In situ Stress 0 psi
Shear Modulus 12000 psi

shift 1.3
Daily Average Water Level Elevation (ft)

Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Date</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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</thead>
<tbody>
<tr>
<td>07/06/07</td>
<td>67.6</td>
<td>12.6</td>
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<td>27.39</td>
<td>25.24</td>
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</table>

VWP (Slope Indicator)

UL-549A

Geotechnical Data Report
Groundwater Data
Sound Transit University Link Explorations // Seattle, WA
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Date</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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<tr>
<td>07/01/07</td>
<td>67.6</td>
<td>-112.4</td>
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<td>--</td>
<td>31.46</td>
<td>29.21</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>07/06/07 18:00</td>
<td>06/07/08 21:13</td>
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</tbody>
</table>

VWP (Slope Indicator)

UL-549B
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
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<th>Date</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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</thead>
<tbody>
<tr>
<td>3/27/08</td>
<td>67.6</td>
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<td>-32.4</td>
<td>-22.4</td>
<td>32.62</td>
<td>32.42</td>
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<td>5/2/08</td>
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UL-549W
Monitoring Well

Geotechnical Data Report
Groundwater Data
Sound Transit University Link Explorations // Seattle, WA
Particle Size Distribution Report

<table>
<thead>
<tr>
<th>SIEVE inches</th>
<th>PERCENT FINER</th>
<th>SIEVE number</th>
<th>PERCENT FINER</th>
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<td>C_u</td>
<td>C_c</td>
<td></td>
</tr>
<tr>
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</tr>
<tr>
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<tr>
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<td>99.9</td>
<td>94.1</td>
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<tr>
<td>#40</td>
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<td>50.0</td>
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<tr>
<td>#200</td>
<td>47.7</td>
<td>52.9</td>
<td>48.6</td>
</tr>
</tbody>
</table>

USC Classification
- silty gravel with sand
- sandy silt
- silty sand

Remarks:
- Classification based on grainsize only
- Classification based on grainsize only

Cobbles | % GRAVEL | % SAND | % SILT | % CLAY | USC | AASHTO | PL | LL |
<table>
<thead>
<tr>
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<td>A-4(0)</td>
<td>NP</td>
<td>NV</td>
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<td>0.0</td>
<td>47.1</td>
<td>52.9</td>
<td>ML</td>
<td>A-4(0)</td>
<td>NP</td>
<td>NV</td>
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<tr>
<td>0.0</td>
<td>1.6</td>
<td>49.8</td>
<td>48.6</td>
<td>SM</td>
<td>A-4(0)</td>
<td>NP</td>
<td>NV</td>
<td></td>
</tr>
</tbody>
</table>

Source of Sample: UL-549
Depth: 54.0-55.0
Sample Number: CC-8

Source of Sample: UL-549
Depth: 68.0-69.0
Sample Number: CC-10

Source of Sample: UL-549
Depth: 98.0-99.0
Sample Number: CC-15

Client: Sound Transit
Project: University Link Project RTA/LR 8-06

Tested By: AJA
Checked By: RGS

SOIL TECHNOLOGY
Bainbridge Island, WA
Atterberg Limits Test Report (ASTM D-4318)

Dashed line indicates the approximate upper limit boundary for natural soils

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>UL-549</td>
<td>CC-12</td>
<td>79.0-80.0</td>
<td>20.4</td>
<td>17</td>
<td>29</td>
<td>12</td>
<td>CL</td>
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<tr>
<td>□</td>
<td>UL-549</td>
<td>ST-13A</td>
<td>88.3-88.7</td>
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<td>51</td>
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<tr>
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<td>UL-549</td>
<td>ST-13A</td>
<td>88.8-89.0</td>
<td>28.5</td>
<td>25</td>
<td>51</td>
<td>26</td>
<td>CH</td>
</tr>
</tbody>
</table>
July 1, 2008

Mr. Rick Smith
Northlink Transit Partners
811 1st Street, Suite 407
Seattle, WA 98105

Re: University Link Final Civil & Architectural Design Project (GTX-7843)

Dear Mr. Smith:

Enclosed are the test results you requested for the above referenced project. GeoTesting Express, Inc. (GTX) received nine soil samples from you between November 1 and December 5, 2007. These samples were labeled as follows:

<table>
<thead>
<tr>
<th>Boring ID</th>
<th>Sample ID</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL-549</td>
<td>ST-13A</td>
<td>89-90 ft</td>
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<tr>
<td>UL-544</td>
<td>ST-13A</td>
<td>80-83 ft</td>
</tr>
<tr>
<td>UL-513</td>
<td>ST-13A</td>
<td>95-98 ft</td>
</tr>
<tr>
<td>UL-526</td>
<td>ST-15,16</td>
<td>84-89 ft</td>
</tr>
<tr>
<td>UL-507</td>
<td>ST-18A</td>
<td>120-123 ft</td>
</tr>
<tr>
<td>UL-507</td>
<td>ST-21</td>
<td>135-136 ft</td>
</tr>
<tr>
<td>UL-535</td>
<td>ST-24A,24B,26B</td>
<td>118-130 ft</td>
</tr>
<tr>
<td>UL-526</td>
<td>ST-60B,63B</td>
<td>301-319 ft</td>
</tr>
<tr>
<td>UL-513</td>
<td>ST-7A,7B,8B,8B</td>
<td>63-80 ft</td>
</tr>
</tbody>
</table>

GTX previously performed and reported the following tests on these samples:

1. Grain Size Analysis (ASTM D 422) with hydrometer
2. Atterberg Limits (ASTM D 4318)
3. CKoU Triaxial Tests
4. Constant Rate of Consolidation Tests (ASTM D 4186)

The following additional tests were requested after completion of the above and the reports are attached:

2. CKoU Triaxial Tests in Extension.

The results presented in this report apply only to the items tested. This report shall not be reproduced except in full, without written approval from GeoTesting Express. The remainder of these samples will be retained for a period of sixty (60) days and will then be discarded unless otherwise notified by you. Please call me if you have any questions or require additional information. Thank you for allowing GeoTesting Express the opportunity of providing you with testing services. We look forward to working with you again in the future.

Respectfully yours,

Joe Tomei
Laboratory Manager
Geotechnical Test Report  

GTX-7843  
University Link  
Final Civil & Architectural Design Project  

Seattle, WA  

Prepared for:  
Northlink Transit Partners
CONSOLIDATED DRAINED TRIAXIAL TEST

Test Run in Extension

| Symbol | ○ |
| Sample No. | ST-25A |
| Test No. | CIDe-2 |
| Depth | 150-153 |
| Diameter, in | 2 |
| Height, in | 4.25 |
| Water Content, % | 20.9 |
| Dry Density, pcf | 107.8 |
| Saturation, % | 100.0 |
| Void Ratio | 0.563 |
| Water Content, % | 25.2 |
| Dry Density, pcf | 100.4 |
| Saturation, % | 100.0 |
| Void Ratio | 0.679 |
| Back Press., psf | 31680 |
| Ver. Eff. Cons. Stress, psf | 10000 |
| Shear Strength, psf | -8955 |
| Strain at Failure, % | -0.651 |
| Stress Rate, psf/min | 0.3481 |
| B-Value | 0.94 |
| Estimated Specific Gravity | 2.7 |
| Liquid Limit | --- |
| Plastic Limit | --- |

Project: University Links Design
Location: Seattle, WA
Project No.: GTX-7843
Boring No.: UL-549
Sample Type: tube
Description: Moist, dark gray clay
Remarks: System T

*Phase calculations based on start and end of test.*

*Saturation is set to 100% for phase calculations.*
CONSOLIDATED DRAINED TRIAXIAL TEST

Test Run in Extension

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Test No.</th>
<th>Depth</th>
<th>Tested By</th>
<th>Test Date</th>
<th>Checked By</th>
<th>Check Date</th>
<th>Test File</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST-25A</td>
<td>CIDe-2</td>
<td>150-153</td>
<td>njh</td>
<td>05/01/08</td>
<td>jdt</td>
<td>7843-CIDe-2AN.dat</td>
<td></td>
</tr>
</tbody>
</table>

GeoTesting express
A subsidiary of Geocomp Corporation

Project: University Links Design  Location: Seattle, WA  Project No.: GTX-7843
Boring No.: UL-549  Sample Type: tube
Description: Moist, dark gray clay
Remarks: System T

Tue, 01-JUL-2008 11:04:39
GTX-7843 UL-549 CIDe

Horizontal Effective Stress (psf)

Axial Strain, %

Client: Northlink Transit Partners
Project Name: University Links Design
Project Location: Seattle, WA
GTX #: 7843
Test Date: 05/12 to 06/17/2008
Tested By: njh
Checked By: jdt
Boring ID: UL-549
Sample ID: ST-25A
Depth, ft: 150-153
WARRANTY and LIABILITY

GeoTesting Express (GTX) warrants that all tests it performs are run in general accordance with the specified test procedures and accepted industry practice. GTX will correct or repeat any test that does not comply with this warranty. GTX has no specific knowledge as to conditioning, origin, sampling procedure or intended use of the material.

GTX may report engineering parameters that require us to interpret the test data. Such parameters are determined using accepted engineering procedures. However, GTX does not warrant that these parameters accurately reflect the true engineering properties of the in-situ material. Responsibility for interpretation and use of the test data and these parameters for engineering and/or construction purposes rests solely with the user and not with GTX or any of its employees.

GTX's liability will be limited to correcting or repeating a test which fails our warranty. GTX's liability for damages to the Purchaser of testing services for any cause whatsoever shall be limited to the amount GTX received for the testing services. GTX will not be liable for any damages, or for any lost benefits or other consequential damages resulting from the use of these test results, even if GTX has been advised of the possibility of such damages. GTX will not be responsible for any liability of the Purchaser to any third party.

Commonly Used Symbols

- A: pore pressure parameter for $\Delta e_1 - \Delta e_3$
- B: pore pressure parameter for $\Delta e_2$
- CIU: isotropically consolidated undrained triaxial shear test
- CR: compression ratio for one dimensional consolidation
- $c_\gamma$: coefficient of curvature, $(D_0)^2 / (D_{10} \times D_{40})$
- $c_s$: coefficient of uniformity, $D_{60} / D_{10}$
- $c_n$: compression index for one dimensional consolidation
- $c_n'$: coefficient of secondary compression
- $c_n''$: coefficient of consolidation
- $c_y'$: cohesion intercept for total stresses
- $c_y''$: cohesion intercept for effective stresses
- D: diameter of specimen
- $D_{10}$: diameter at which 10% of soil is finer
- $D_{15}$: diameter at which 15% of soil is finer
- $D_{25}$: diameter at which 30% of soil is finer
- $D_{50}$: diameter at which 50% of soil is finer
- $D_{60}$: diameter at which 60% of soil is finer
- $D_{85}$: diameter at which 85% of soil is finer
- $d_{50}$: displacement for 50% consolidation
- $d_{95}$: displacement for 95% consolidation
- $d_{100}$: displacement for 100% consolidation
- E: Young's modulus
- $e_v$: void ratio
- $e_v'$: void ratio after consolidation
- $e_v''$: initial void ratio
- G: shear modulus
- $G_s$: specific gravity of soil particles
- H: height of specimen
- PI: plasticity index
- i: gradient
- $K_p$: lateral stress ratio for one dimensional strain
- k: permeability
- L: liquidity index
- $m_p$: coefficient of volume change
- n: porosity
- PI: plasticity index
- $P_c$: preconsolidation pressure
- $p$ = $(\sigma_1 + \sigma_3) / 2$, $(\sigma_1 + \sigma_3) / 2$
- $p'$ = $(\sigma_1' + \sigma_2') / 2$, $(\sigma_1' + \sigma_2') / 2$
- $p''$: $p'$ at consolidation
- Q: quantity of flow
- $q$ = $(\sigma_1 - \sigma_3) / 2$
- $q_f$: $q$ at failure
- $q_i$: initial $q$
- $q_{s_t}$: $q$ at consolidation
- S: degree of saturation
- SL: shrinkage limit
- $s_u$: undrained shear strength
- T: time factor for consolidation
- $t$: temperature
- $\gamma$: time
- $U_s$, UC: unconfined compression test
- $U_{uu}$, Q: unconfined undrained triaxial test
- $u_p$: pore gas pressure
- $u_r$: excess pore water pressure
- $u_w$: pore water pressure
- V: total volume
- $V_s$: volume of gas
- $V_s$: volume of solids
- $V_v$: volume of voids
- $V_w$: volume of water
- $V_o$: initial volume
- V: velocity
- W: total weight
- $W_s$: weight of solids
- $W_w$: weight of water
- w: water content
- $w_{ac}$: water content at consolidation
- $w_{f}$: final water content
- $w_l$: liquid limit
- $w_s$: natural water content
- $w_p$: plastic limit
- $w_s$: shrinkage limit
- $w_{ai}$, $w_{li}$: initial water content
- $a$: slope of $q_t$ versus $p_t$
- $a'$: slope of $q_t$ versus $p_t'$
- $t_{ii}$: total unit weight
- $d_{dry}$: dry unit weight
- $u$: unit weight of solids
- $w_s$: unit weight of water
- $e_v$: strain
- $e_{vol}$: volume strain
- $e_{h}$: horizontal strain, vertical strain
- $\mu$: Poisson's ratio, also viscosity
- $\sigma$: normal stress
- $\sigma'$: effective normal stress
- $\sigma_{un}$, $\sigma_{on}$: consolidation stress in isotropic stress system
- $\sigma_{ns}$, $\sigma_{ns}'$: horizontal normal stress
- $\sigma_{ns}$, $\sigma_{ns}'$: vertical normal stress
- $d_{m}$: major principal stress
- $d_{i}$: intermediate principal stress
- $d_{p}$: minor principal stress
- $r$: shear stress
- $\phi$: friction angle based on total stresses
- $\phi'$: friction angle based on effective stresses
- $\phi_r$: residual friction angle
- $\phi_{ul}$: $\phi$ for ultimate strength
Geotechnical Engineering Laboratory

CONSOLIDATION TEST SUMMARY

Client: Sound Transit  
Project: University Link  
Location: Seattle, WA  
Project No: RTA/LR 8-06

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Initial</th>
<th>Final</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Content (%)</td>
<td>28.1</td>
<td>24.1</td>
</tr>
<tr>
<td>Total Mass (gm)</td>
<td>144.2</td>
<td>139.7</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.75</td>
<td>2.75</td>
</tr>
<tr>
<td>Dry Density (pcf)</td>
<td>97.07</td>
<td></td>
</tr>
<tr>
<td>Height (in)</td>
<td>2.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Diameter (in)</td>
<td>0.900</td>
<td></td>
</tr>
<tr>
<td>Void Ratio:</td>
<td>0.768</td>
<td></td>
</tr>
<tr>
<td>Saturation (%)</td>
<td>100.6</td>
<td></td>
</tr>
</tbody>
</table>

Atterberg Limits
- LL: 51
- PL: 25
- PI: 26

Test Results
- Preconsolidation Pressure (psf): 9,443
- Compression Ratio, CR: 0.117
- Recompression Ratio, RR: 0.022
- Swell Pressure (psf): N/A

Notes:
1. Consolidation performed in accordance with ASTM D4186.
2. CR and RR calculated as the change in strain divided by the change in log stress.
Vertical Strain, $e$, [%]
Vertical Effective Stress, $\sigma'$, [psf]

Exploration No: UL-549
Sample No: ST-13A
Depth (ft): 88.8-89.0
Sample Description: Stiff, moist, grey, Clay (CH)

Preconsolidation Pressure (psf): 9,443
Compression Ratio, CR: 0.117
Recompression Ratio, RR: 0.022
Exploration No: UL-549  
Sample No: ST-13A  
Depth (ft): 88.8-89.0  
Sample Description: Stiff, moist, grey, Clay (CH)

Preconsolidation Pressure (psf): 9.443  
Compression Ratio, CR: 0.117  
Recompression Ratio, RR: 0.022

Client: Sound Transit  
Project: University Link  
Project No: RTA/LR 8-06
Exploration No: UL-549
Sample No: ST-13A
Depth (ft): 88.8-89.0
Sample Description: Stiff, moist, grey, Clay (CH)

Preconsolidation Pressure (psf): 9,443
Compression Ratio, CR: 0.117
Recompression Ratio, RR: 0.022

Client: Sound Transit
Project: University Link
Project No: RTA/LR 8-06

CONSOLIDATION TEST
ASTM D4186
Exploration No: UL-549
Sample No: ST-13A
Depth (ft): 88.8-89.0
Sample Description: Stiff, moist, grey, Clay (CH)

Preconsolidation Pressure (psf): 9,443
Compression Ratio, CR: 0.117
Recompression Ratio, RR: 0.022
Constant Rate of Consolidation
Constant Strain Rate by ASTM D4186
Summary Report

Strain, %

Effective Stress, psi

10^9

10^-1

10^-2

10^-3

10^-4

10^-5

10^-6

10^-7

1
10
100
1000

1
10
100
1000

Project: University Links Design  Location: Seattle, WA  Project No.: GTX-7843
Boring No.: UL-549  Tested By: md  Checked By: jdt
Sample No.: ST-13A  Test Date: 01/22/08  Depth: 89-90 ft
Test No.: CRS-7  Sample Type: tube  Elevation: ---
Description: Moist, greenish gray clay
Remarks: System P
**CRC TEST DATA**

**Project:** University Links Design  
**Boxing No.:** UL-549  
**Sample No.:** ST-13A  
**Test No.:** CRS-7

**Location:** Seattle, WA  
**Tested By:** nd  
**Test Date:** 01/22/08  
**Sample Type:** tube

**Soil Description:** Moist, greenish gray clay  
**Remarks:** System P

**Estimated Specific Gravity:** 2.92  
**Initial Void Ratio:** 0.90  
**Final Void Ratio:** 0.68  

**Liquid Limit:** 51  
**Plastic Limit:** 23  
**Plasticity Index:** 28

**Initial Height:** 1.00 in  
**Specimen Diameter:** 2.50 in

<table>
<thead>
<tr>
<th>Container ID</th>
<th>Wt. Container + Wet Soil, gm</th>
<th>Wt. Container + Dry Soil, gm</th>
<th>Wt. Container, gm</th>
<th>Wt. Dry Soil, gm</th>
<th>Water Content, %</th>
<th>Void Ratio</th>
<th>Degree of Saturation, %</th>
<th>Dry Unit Weight, pcf</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>212.1</td>
<td>170.02</td>
<td>8.12</td>
<td>161.9</td>
<td>25.59</td>
<td>---</td>
<td>82.80</td>
<td>95.958</td>
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<tr>
<td></td>
<td>371.7</td>
<td>340.17</td>
<td>216.53</td>
<td>123.64</td>
<td>25.50</td>
<td>0.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>369.05</td>
<td>340.17</td>
<td>216.53</td>
<td>123.64</td>
<td>23.35</td>
<td>0.68</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>160.23</td>
<td>131.43</td>
<td>8.12</td>
<td>123.32</td>
<td>23.35</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Specific Gravity and Void Ratios are calculated assuming the degree of saturation equals 100% at the end of the test. Therefore, values may not represent actual values for the specimen.
<table>
<thead>
<tr>
<th>Test Comments</th>
<th>UC/CL</th>
<th>AppL</th>
<th>Depth</th>
<th>Geographic Unit</th>
<th>UGS</th>
<th>Shipment Number 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>We are trying to get 3 COXU tests.</td>
<td>CH/CL</td>
<td>AppL</td>
<td>69-90</td>
<td>UL549 ST13A</td>
<td>89-90</td>
<td>November 20 Geo Testing Shipment Number 2</td>
</tr>
</tbody>
</table>

To obtain the max. pass pressure, we are trying to get 2 COXU tests. | CH/CL | AppL | 80-85 | UL544 ST13A | 80-85 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 135-136 | UL607 ST121 | 135-136 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 69-90 | UL556 ST115 | 69-90 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-320 | UL566 ST16B | 319-320 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-319 | UL656 ST176 | 319-319 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-320 | UL566 ST16B | 319-320 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-319 | UL656 ST176 | 319-319 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-320 | UL566 ST16B | 319-320 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-319 | UL656 ST176 | 319-319 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-320 | UL566 ST16B | 319-320 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 319-319 | UL656 ST176 | 319-319 |

We are trying to get 2 COXU tests. | CH/CL | AppL | 301-302 | UL566 ST16B | 301-302 |
UL-550
### PRESSUREMETER DATA

**North Transit Partners**

**Link Light Rail Project University Link**

**Hole No. UL 550**

**Depth** 19ft

File C:\DATA\C-326\ST52.P

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
<th>Radial Displacement / Radius(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>250</td>
<td>3</td>
</tr>
<tr>
<td>500</td>
<td>6</td>
</tr>
<tr>
<td>750</td>
<td>9</td>
</tr>
<tr>
<td>1000</td>
<td>12</td>
</tr>
</tbody>
</table>

- **Field Data**
- **Shear Modulus**

**Shear Modulus** 110233 psi

**Shear Modulus** 36419 psi

**Hughes**

*shift 0*
### PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link

<table>
<thead>
<tr>
<th>Hole No.</th>
<th>Depth</th>
<th>File</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL 550</td>
<td>19ft</td>
<td>C:\DATA\C-326\ST52.P</td>
</tr>
</tbody>
</table>

Field Data

- **Shear Modulus**: 7471 psi
- **Shear Modulus**: 110233 psi

Shear Modulus 110233 psi

Shear Modulus 7471 psi

![Graph]

- **Pressure (psi)**
  - 0
  - 250
  - 500
  - 750
  - 1000

- **Radial Displacement / Radius (%)**
  - 0
  - 3
  - 6
  - 9
  - 12

shift 0

HUGHES
Hole No. UL 550  Depth 19ft

Field Data

Shear Strength 554.4 psi
Limit Pressure 1909 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 550 Depth 19ft File C:\DATA\C-326\ST52.P

GIBSON'S CLAY MODEL
Shear Strength 300 psi
In situ Stress 150 psi
Shear Modulus 12000 psi

Field Data
Clay Model Curve
Undrained Stress Strain Curve
### PRESSUREMETER DATA

**North Transit Partners**

**Link Light Rail Project University Link**  
6-22-07  
Hole No. UL 550  
Depth 19ft  
File C:\DATA\C-326\ST52.P

<table>
<thead>
<tr>
<th>Pressure (psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>250</td>
</tr>
<tr>
<td>500</td>
</tr>
<tr>
<td>750</td>
</tr>
<tr>
<td>1000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radial Displacement / Radius(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>6</td>
</tr>
<tr>
<td>9</td>
</tr>
<tr>
<td>12</td>
</tr>
</tbody>
</table>

### THE HUGHES SAND MODEL

- **Water Pressure**: 0 psi  
- **Friction Angle**: 40 deg  
- **Critical Friction Angle**: 32 deg  
- **Lateral Stress**: 40 psi  
- **Shear Modulus**: 60000 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 550 Depth 19ft
File C:\DATA\C-326\ST52U.P

Field Data
Slope of Log Normal Data

Shear Strength 105.9 psi
Limit Pressure 1192 psi

shift 4.7
HUGHES
Hole No. UL 550  Depth 19ft  File C:\DATA\C-326\ST52U.P

GIBSON'S CLAY MODEL
Shear Strength 250 psi
In-situ Stress 0 psi
Shear Modulus 100000 psi

Radial Displacement / Radius(%) (Shear Strain/2)
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Date</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/207</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
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<tr>
<td>9/21/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>9/25/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>10/5/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>10/9/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>10/13/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>10/17/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>10/21/07</td>
<td>67.0</td>
<td>-8.0</td>
<td>--</td>
<td>--</td>
<td>34.80</td>
<td>31.79</td>
</tr>
<tr>
<td>10/25/07</td>
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<td>-8.0</td>
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<td>--</td>
<td>34.80</td>
<td>31.79</td>
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<tr>
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Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.
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UL-550Wx
VWP (Slope Indicator)
Particle Size Distribution Report

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USC Classification
- □ poorly graded sand
- □ poorly graded sand with silt
- △ poorly graded sand

Remarks:
- ○ Classification based on grain size only
- □ Classification based on grain size only
- △ Classification based on grain size only

Source of Sample: UL-550
- Depth: 40.0-41.0
- Sample Number: CC-5

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195
Figure: 25

Cobbles | % GRAVEL | % SAND | % SILT | % CLAY | USCS | AASHTO | PL | LL
---|-----------|---------|---------|---------|------|---------|----|----
0.00 | 0.2 | 98.9 | 0.9 | | SP | A-1-b | NP | NV
0.00 | 2.7 | 90.0 | 7.3 | | SP-SM | A-3 | NP | NV
0.16 | 1.6 | 94.5 | 3.9 | | SP | A-3 | NP | NV

SOIL TECHNOLOGY
Bainbridge Island, WA

Tested By: □ RMD □ AJA △ RMD
Checked By: RGS
### Particle Size Distribution Report

#### Soil Technology

**Bainbridge Island, WA**

- **Client:** Sound Transit
- **Project:** University Link Project RTA/LR 8-06
- **Project No.:** J-07-2195

- **Tested By:** AJA
- **Checked By:** RGS

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- **USC Classification:**
  - ○ silty sand

- **Remarks:**
  - ○ Classification based on grainsize only

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- **Source of Sample:** UL-550
- **Depth:** 129.0-130.0
- **Sample Number:** CC-11
Hole No. UL 551  Depth 43 ft  File C:\DATA\C-326\ST55.P

Shear Modulus  61111 psi
Shear Modulus  94444 psi
PRESSUREMETER DATA  
North Transit Partners
Link Light Rail Project University Link  
07/02/07
Hole No. UL 551  
Depth 43ft  
File C:\DATA\C-326\ST55.P

Field Data
Shear Modulus

Shear Modulus 3927 psi
Shear Modulus 6111 psi

Pressure (psi)

Radial Displacement / Radius(%)
Shear Strength 210.4 psi
Limit Pressure 965 psi
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 07/02/07
Hole No. UL 551 Depth 43ft File C:\DATA\C-326\ST55.P

HUGHES

GIBSON'S CLAY MODEL

Shear Strength 110 psi
Insitu Stress 70 psi
Shear Modulus 60000 psi

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

Pressure (psi)
Radial Displacement / Radius(%) (Shear Strain/2) shift 0

Hughes
PRESSUREMETER DATA
North Transit Partners

Link Light Rail Project University Link 07/02/07
Hole No. UL 551 Depth 43ft
File C:\DATA\C-326\ST55U.P

---

Shear Strength 18 psi
Limit Pressure 754 psi

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shift 1.4
Hole No. UL 551 Depth 43ft File C:\DATA\C-326\ST55U.P

Pressure (psi)

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

Radial Displacement / Radius(%) (Shear Strain/2)

GIBSON'S CLAY MODEL
Shear Strength 200 psi
In situ Stress 0 psi
Shear Modulus 80000 psi

shift 1.4

HUGHES
Hole No. UL 551  Depth 63ft  File C:\DATA\C-326\ST56.P

Field Data

Shear Modulus 75833 psi
Shear Modulus 55151 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link 7-3-07
Hole No. UL 551 Depth 63ft File C:\DATA\C-326\ST56U.P

Shear Strength 283.6 psi
Limit Pressure 1694 psi

Field Data
Slope of Log Normal Data

Log Radial Displacement / Radius(%)
PRESSUREMETER DATA  
North Transit Partners  
Link Light Rail Project University Link  
7-3-07  
Hole No. UL 551  
Depth 63ft  
File C:\DATA\C-326\ST56U.P

GIBSON'S CLAY MODEL

Shear Strength 230 psi
Insitu Stress 0 psi
Shear Modulus 80000 psi

Radial Displacement / Radius(%) (Shear Strain/2)
PRESSUREMETER DATA

Link Light Rail Project University Link
Hole No. UL 551 Depth 73ft
File C:\DATA\C-326\ST57.P

HUGHES

Shear Modulus  42051 psi

Shear Modulus  50555 psi
Hole No. UL 551  
Depth 73ft  
File C:\DATA\C-326\ST57.P

Pressure

Radial Displacement / Radius(%)

Field Data
Shear Modulus

Shear Modulus 6094 psi
Shear Modulus 42051 psi
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 7-3-07

Hole No. UL 551 Depth 73ft File C:\DATA\C-326\ST57.P

Shear Strength 347.4 psi
Limit Pressure 1409 psi
PRESSUREMETER DATA
North Transit Partners
Link Light Rail Project University Link
Hole No. UL 551 Depth 73ft
File C:\DATA\C-326\ST57.P

GIBSON'S CLAY MODEL
Shear Strength 180 psi
In situ Stress 50 psi
Shear Modulus 30000 psi

Field Data
- Clay Model Curve
- Undrained Stress Strain Curve

Pressure (psi)

Radial Displacement / Radius(%) (Shear Strain/2)

HUGHES
PRESSUREMETER DATA

North Transit Partners

Link Light Rail Project University Link 7-3-07
Hole No. UL 551 Depth 73ft File C:\DATA\C-326\ST57U.P

Shear Strength 194.2 psi
Limit Pressure 1321 psi

shift 5.4
Field Data
Clay Model Curve
Undrained Stress Strain Curve

GIBSON'S CLAY MODEL

Shear Strength 180 psi
In-situ Stress 0 psi
Shear Modulus 80000 psi

shift 5.4
Wilson Ihrig and Associates.
5776 Broadway
Oakland, California 94618

Compression and Shear Wave Velocity Measurements
Borings UL 546 and UL 551
Puget Sound Transit Consultants, Seattle, WA

This report presents the results of the geophysical measurements in Borings UL 546 and UL 551, Puget Sound Transit Central Link Light Rail, for Puget Sound Transit Consultants, Seattle, Washington. UL 551 is located opposite the University of Washington football Stadium and UL 546 is located in the U of W Stadium parking area. Compression and Shear wave velocities for dynamic soil moduli determinations were measured in the borings on August 15 and 16, 2007.

COMPRESSION AND SHEAR WAVE VELOCITIES

The boring was cased with 2-inch Schedule 40 PVC pipe. The 2-inch casing was backfilled in the borehole annulus with a bentonite/cement grout mixture.

The measured compression and shear wave velocities are presented in the tables attached to this report. The tables show the depths down the bore hole, the field measured interval times, the converted vertical downhole time arrivals, the interval vertical velocities in the boring, and the averaged velocities over the measured intervals. When the velocity boundary does not coincide with a measurement depth, the velocity calculation of that point is not accurate from the preceding point of measurement, and the velocity computation between those two points is not included in the velocity average.
Compression and Shear Wave Velocities, UL 546 and 551  
Wilson Ihrig and Associates.

Figures 1 and 2 are the time-depth plots for the borings. The plots are the corrected downhole time arrivals of the measured Compression (P) and Shear (S) wave particle motion, plotted against the depth of measurement. The velocities of the P and S waves are computed from the slopes of the time arrivals on the figures, or as the averaged velocities of the interval velocities. The figures were utilized to determine the depths of the velocity layers in the attached tables and summaries presented below.

The summaries of the measured P and S wave velocities in the borings are as follows:

**Boring UL 546**

<table>
<thead>
<tr>
<th>Depth of Data (feet)</th>
<th>P-wave Velocity (feet/second)</th>
<th>S-wave Velocity (feet/second)</th>
<th>Poisson's Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 11</td>
<td>5026</td>
<td>728</td>
<td>0.4893</td>
</tr>
<tr>
<td>11 to 52</td>
<td>7450</td>
<td>1770</td>
<td>0.4701</td>
</tr>
<tr>
<td>52 to 110</td>
<td>7036</td>
<td>1451</td>
<td>0.4778</td>
</tr>
</tbody>
</table>

**Boring UL 551**

<table>
<thead>
<tr>
<th>Depth of Data (feet)</th>
<th>P-wave Velocity (feet/second)</th>
<th>S-wave Velocity (feet/second)</th>
<th>Poisson's Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 to 20</td>
<td>5971</td>
<td>1245</td>
<td>0.4773</td>
</tr>
<tr>
<td>20 to 60</td>
<td>6915</td>
<td>1560</td>
<td>0.4732</td>
</tr>
<tr>
<td>60 to 140</td>
<td>7613</td>
<td>1745</td>
<td>0.4722</td>
</tr>
</tbody>
</table>

Poisson's Ratio is calculated as follows:

\[
\mu = \frac{V_p^2 - 2V_s^2}{2(V_s^2 - V_p^2)}
\]

Where:  
\(\mu\) = Poisson's Ratio  
\(V_p\) = Compression Wave Velocity  
\(V_s\) = Shear Wave Velocity

The Compression (P) wave energy was generated by a vertical blow to a metal plate placed on the surface, offset from the casing. The zero time of the hammer blow was determined from an impact switch taped to the hammer. Multiple hammer blows were stacked to enhance the downhole energy arrivals.
The Shear (S) Wave energy source was a 6 by 6-inch plank offset from the casing. The front wheels of a vehicle were placed on the top of the plank to provide coupling with the ground surface. The long direction of the plank was placed tangent to a circle with the radius center at the borehole. An impact switch taped to the handle of the hammer determined zero time.

The source offset from the borehole provides a wave travel path that is in soil that is generally not within the soils adjacent to the borehole, that are disturbed by the drilling operation. The disturbed soil zone may be considered to be relatively constant from the top of the boring to the bottom.

Three detectors, spaced at 10-foot intervals in the borehole, were used to detect the generated S wave energy. To minimize the effect of the detector spiral as they are lowered down the borehole; each detector package contains four sets of horizontal geophones (8 Hz geophones) placed on axes of 45 degrees. The axis of sensitivity of the geophones is 20 degrees.

For the S wave data, two recordings were made at each data point. The two separate recordings were made with reversed (polarized) energy inputs utilizing the opposite ends of the plank (blows right and left). The time arrival of the shear wave energy was determined by comparing arrival times and direction of particle motion of the recorded wave motion in the two data sets.

The particle motion of the shear wave energy is polarized and is dependent on the direction of the energy input. On Blow 1, the particle motion is reversed from that produced by Blow 2. The polarization of the energy helps the interpreter to separate S wave arrivals from other energy arrivals and noise. Reversed particle motion, however, can also occur in other ways such as out-of-phase noise, shear energy generated in the boring annulus backfill and casing as tube waves and P to S conversions. Continuity of the energy arrivals from the surface to the bottom of the hole helps separate these various energy arrivals.

A data sample of the Shear wave data made in Boring UL 546 at a depth of 45 feet is presented below. The vertical cursor is at the point picked as the shear wave arrival time, with the arrival time displayed below the cursor. There are 500 samples across the image, with sample number 240 on the left side of the record (equal to 24 milli-Seconds; each tick mark is 2 ms). The shear wave arrival is shown on Trace 7. Trace 8 is 45 degrees to Trace 7. Trace 5 is 90 degrees to Trace 7. The other reversed energy arrivals are a result of the orientation of the detector package to that of the polarized shear wave and random noise. The detectors will spiral down the casing as they are lowered in the casing so that the orientation of the detector package varies with depth.
The picked arrival times were converted from the "slant distance" travel path to the vertical travel path down the borehole. The "slant distance" travel path is a result of the source to borehole offset. The formula used for the conversion to the 'Corrected Time' vertically down the borehole is:

\[ DH \text{ Time} = \text{Record Time} \times [\cos(\arctan(\text{offset/detector depth}))] \]

Borehole drift was not measured in the boring, and no corrections have been applied for possible drift. The velocity changes generally correspond to the logged material changes, so that extreme drift of the borings off of vertical is not expected.

The recording equipment was a Geometrics 1225, a 12-channel signal enhancement digital-recording seismograph. The P wave was measured using a 25-millisecond record length and the S wave was measured with 50 and 100 millisecond record lengths, with various amounts of delay times. The sampling rate was 1000 samples per record length; the samples are an 8 bit word. The data was field recorded on a laptop computer in SEG-1 format. Arrival times were picked from a computer screen image of the records.

The information presented in this report is based upon geophysical measurements made by generally accepted methods and field procedures, and our interpretation of these data. The presented information is based upon our best estimate of subsurface conditions.
considering the geophysical results and all other information available to us. These results are interpretive in nature and are considered to be a reasonably accurate presentation of the existing conditions within the limitations of the method or methods employed.

For Geo-Recon International:

John M. Musser Jr.
Principal Geophysicist
# Downhole Compressional and Shear Wave Velocity Measurements

## Borehole: UL-551 - Puget Sound Transit/University LLink Light Rail Seattle, Washington

## Shear Wave Data - Interval Velocity Computations

<table>
<thead>
<tr>
<th>Depth of Data</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>18.60</td>
<td>12.182</td>
<td>12.182</td>
<td>n/a</td>
<td>n/a</td>
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</table>

### Velocity Change at ~ 5 feet

<table>
<thead>
<tr>
<th>Depth</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.0</td>
<td>20.20</td>
<td>16.160</td>
<td>3.978</td>
<td>1257</td>
<td>1245</td>
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<tr>
<td>15.0</td>
<td>22.80</td>
<td>20.393</td>
<td>4.233</td>
<td>1181</td>
<td>1245</td>
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<td>20.0</td>
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<td>24.251</td>
<td>3.658</td>
<td>1296</td>
<td>1245</td>
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### Velocity Change at ~ 20 feet

<table>
<thead>
<tr>
<th>Depth</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>25.0</td>
<td>26.60</td>
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<td>1560</td>
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<td>30.0</td>
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<tr>
<td>35.0</td>
<td>34.80</td>
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<tr>
<td>45.0</td>
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<td>40.344</td>
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<td>50.0</td>
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<tr>
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<tr>
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<td>49.912</td>
<td>3.414</td>
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<td>1560</td>
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### Velocity Change at ~ 60 feet

<table>
<thead>
<tr>
<th>Depth</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>65.0</td>
<td>53.10</td>
<td>52.750</td>
<td>2.838</td>
<td>1762</td>
<td>1746</td>
</tr>
<tr>
<td>70.0</td>
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<td>55.681</td>
<td>2.931</td>
<td>1706</td>
<td>1746</td>
</tr>
<tr>
<td>75.0</td>
<td>58.90</td>
<td>58.608</td>
<td>2.926</td>
<td>1709</td>
<td>1746</td>
</tr>
<tr>
<td>80.0</td>
<td>61.70</td>
<td>61.431</td>
<td>2.823</td>
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<td>1746</td>
</tr>
<tr>
<td>85.0</td>
<td>64.50</td>
<td>64.250</td>
<td>2.820</td>
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<td>1746</td>
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<td>90.0</td>
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<td>1746</td>
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<td>1746</td>
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<td>1746</td>
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<td>110.0</td>
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<td>78.518</td>
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<td>1746</td>
</tr>
<tr>
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<td>81.277</td>
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<td>120.0</td>
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<td>84.186</td>
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<td>3.007</td>
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<td>95.763</td>
<td>2.806</td>
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</tbody>
</table>

Source to Borehole offset: 7.5 feet.  Velocity in feet per second.
Casing stickup above ground: 0 feet.  Depths in feet - Times in milli-seconds.
n/a - Not included in Velocity Average. Velocity breaks from Time-Depth Plot.
Elevation Difference between Source and Top of Casing: 0 ft.
Downhole Compressional and Shear Wave Velocity Measurements

**Borehole: UL-551 - Puget Sound Transit/University Link Light Rail**
**Seattle, Washington**

**Compressional Wave Data - Interval Velocity Computations**

<table>
<thead>
<tr>
<th>Depth of Data</th>
<th>Recorded Time</th>
<th>Corrected Time</th>
<th>Interval Time</th>
<th>Interval Velocity</th>
<th>Average Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>1.800</td>
<td>0.998</td>
<td>0.9985</td>
<td>n/a</td>
<td>n/a</td>
</tr>
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</table>

**Velocity Change at ~ 5 feet**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
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</tr>
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<tbody>
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<td>10.0</td>
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**Velocity Change at ~ 20 feet**

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<thead>
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<td>25.0</td>
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<td>9.400</td>
<td>9.296</td>
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</table>

**Velocity Change at ~ 60 feet**

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
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<td>10.050</td>
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</table>

Source to Borehole offset: 9 feet.
Casing stickup above ground: 0 feet.
n/a - Not included in Velocity Average.
Velocity Breaks from Time-Depth Plot.
Elevation Difference between Source and Top of Casing: 0 ft.

Velocities in feet per second.
Depths in feet - Times in milli-seconds.
UL- 551 - Puget Sound Transit/University Light Rail
Compression and Shear Wave Velocities

- Shear Wave Arrivals
- Compressional Wave Arrival

Figure 2
<table>
<thead>
<tr>
<th>Date</th>
<th>Water Level Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
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Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.
 Daily Average Water Level Elevations (ft)

Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

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<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
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VWP (Slope Indicator)

UL-551Wx
29 April 2008

Dave Rugh
Aspect Consulting
401 Second Avenue, Suite 201
Seattle, WA 98104

RE: 060058, Sound Transit Ulink
ARI Job: MS53

Dear Dave:

Please find enclosed the original chain of custody (COC) record and the final results for samples from the project referenced above. Analytical Resources, Inc. accepted seven water samples in good condition on April 16, 2008. The samples were analyzed for methane, VOAs, BETX/NWTPH-G, NWTPH-Dx, hardness, total and dissolved metals and conventional parameters as requested.

These analysis proceeded without incident of note.

Electronic copies of these reports and all raw data will be kept on file at ARI. If you have questions or require additional information, please feel free to contact me at your convenience.

Sincerely,

ANALYTICAL RESOURCES, INC.

Mark D. Harris
Project Manager
206/695-6210
markh@arilabs.com

Enclosures

cc: File MS53

MDH/mdh
Chain of Custody Record & Laboratory Analysis Request

<table>
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<tr>
<th>Sample ID</th>
<th>Date</th>
<th>Time</th>
<th>Matrix</th>
<th>No. Containers</th>
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<td>X</td>
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Comments/Special Instructions:
Email lab report to drugh@aspectconsulting.com

Limits of Liability: ARI will perform all requested services in accordance with appropriate methodology following ARI Standard Operating Procedures and the ARI Quality Assurance Program. This program meets standards for the industry. The total liability of ARI, its officers, agents, employees, or successors, arising out of or in connection with the requested services, shall not exceed the Invoiced amount for said services. The acceptance by the client of a proposal for services by ARI release ARI from any liability in excess thereof, not withstanding any provision to the contrary in any contract, purchase order or co-signed agreement between ARI and the Client.

Sample Retention Policy: All samples submitted to ARI will be appropriately discarded no sooner than 90 days after receipt or 60 days after submission of hardcopy data, whichever is longer, unless alternate retention schedules have been established by work-order or contract.
ARI Data Reporting Qualifiers
Effective 11/22/04

Inorganic Data

U Indicates that the target analyte was not detected at the reported concentration
* Duplicate RPD is not within established control limits
B Reported value is less than the CRDL but ≥ the Reporting Limit
N Matrix Spike recovery not within established control limits
NA Not Applicable, analyte not spiked
H The natural concentration of the spiked element is so much greater than the concentration spiked that an accurate determination of spike recovery is not possible
L Analyte concentration is ≤5 times the Reporting Limit and the replicate control limit defaults to ±1 RL instead of the normal 20% RPD

Organic Data

U Indicates that the target analyte was not detected at the reported concentration
* Flagged value is not within established control limits
B Analyte detected in an associated Method Blank at a concentration greater than one-half of ARI’s Reporting Limit or 5% of the regulatory limit or 5% of the analyte concentration in the sample.
J Estimated concentration when the value is less than ARI’s established reporting limits
D The spiked compound was not detected due to sample extract dilution
NR Spiked compound recovery is not reported due to chromatographic interference
E Estimated concentration calculated for an analyte response above the valid instrument calibration range. A dilution is required to obtain an accurate quantification of the analyte.
S Indicates an analyte response that has saturated the detector. The calculated concentration is not valid; a dilution is required to obtain valid quantification of the analyte
NA The flagged analyte was not analyzed for
NS The flagged analyte was not spiked into the sample
M Estimated value for an analyte detected and confirmed by an analyst but with low spectral match parameters. This flag is used only for GC-MS analyses
N The analysis indicates the presence of an analyte for which there is presumptive evidence to make a “tentative identification”
Y The analyte reporting limit is raised due to a positive chromatographic interference. The compound is not detected above the raised limit but may be present at or below the limit
C The analyte was positively identified on only one of two chromatographic columns. Chromatographic interference prevented a positive identification on the second column
P The analyte was detected on both chromatographic columns but the quantified values differ by ≥40% RPD with no obvious chromatographic interference
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<th>CAS Number</th>
<th>Analyte</th>
<th>RL</th>
<th>Result</th>
<th>Q</th>
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<td>Chloromethane</td>
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<td>U</td>
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<td>74-83-9</td>
<td>Bromomethane</td>
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<td>&lt; 0.5 U</td>
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<td>75-01-4</td>
<td>Vinyl Chloride</td>
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<td>Chloroethane</td>
<td>0.2</td>
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<tr>
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<tr>
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<tr>
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**ORGANICS ANALYSIS DATA SHEET**  
**Volatiles by Purge & Trap GC/MS-Method SW8260B**  
**Sample ID:** MB-041708  
**METHOD BLANK**  

**Lab Sample ID:** MB-041708  
**LIMS ID:** 08-0000  
**Matrix:** Water  
**Date Analyzed:** 04/17/08 09:49  
**QC Report No:** MS53-Aspect Consulting  
**Project:** Sound Transit ULink  
**060058**

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<th>CAS Number</th>
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<th>RL</th>
<th>Result (μg/L)</th>
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</thead>
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<td>110-57-6</td>
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<td>87-68-3</td>
<td>Hexachlorobutadiene</td>
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<td>106-93-4</td>
<td>Ethylene Dibromide</td>
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<td>1,2,3-Trichlorobenzene</td>
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Reported in μg/L (ppb)  

**Volatile Surrogate Recovery**

- d4-1,2-Dichloroethane: 107%  
- d8-Toluene: 96.8%  
- Bromofluorobenzene: 97.5%  
- d4-1,2-Dichlorobenzene: 99.0%

**FORM I**
<table>
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<th>CAS Number</th>
<th>Analyte</th>
<th>RL</th>
<th>Result</th>
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<td>74-87-3</td>
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<td>Chloroethane</td>
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<td>75-09-2</td>
<td>Methylene Chloride</td>
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Reported in μg/L (ppb)

**Volatile Surrogate Recovery**

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<tr>
<td>d4-1,2-Dichloroethane</td>
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<td>d8-Toluene</td>
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<tr>
<td>Bromofluorobenzene</td>
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<td>d4-1,2-Dichlorobenzene</td>
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**ORGANICS ANALYSIS DATA SHEET**

**Volatile by Purge & Trap GC/MS-Method SW8260B**  
**Sample ID: UL-551-041508**  
**Lab Sample ID: MS53F**  
**LIMS ID: 08-7959**  
**Matrix: Water**  
**Data Release Authorized:**  
**Reported:** 04/24/08

**QC Report No:** MS53-Aspect Consulting  
**Project:** Sound Transit U Link  
**060058**  
**Date Sampled:** 04/15/08  
**Date Received:** 04/16/08  
**Sample Amount:** 20.0 mL  
**Purge Volume:** 20.0 mL

**Instrument/Analyst:** FINN3/PAB  
**Date Analyzed:** 04/22/08 15:22

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Reported in µg/L (ppb)

**Volatile Surrogate Recovery**

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<td>d8-Toluene</td>
<td>101%</td>
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<tr>
<td>Bromofluorobenzene</td>
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<td>CAS Number</td>
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<tr>
<td>74-87-3</td>
<td>Chloromethane</td>
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<td>74-83-9</td>
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Sample Amount: 20.0 mL
Purge Volume: 20.0 mL
ORGANICS ANALYSIS DATA SHEET
Volatiles by Purge & Trap GC/MS-Method SW8260B

Sample ID: TRIP BLANK SAMPLE

Lab Sample ID: MS53I
LIMS ID: 08-8000
Matrix: Water
Date Analyzed: 04/17/08 15:39

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Reported in µg/L (ppb)

Volatile Surrogate Recovery

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ORGANICS ANALYSIS DATA SHEET
Volatiles by Purge & Trap GC/MS-Method SW8260B
Page 2 of 2

Lab Sample ID: LCS-041708
LIMS ID: 08-8000
Matrix: Water

QC Report No: MS53-Aspect Consulting
Project: Sound Transit ULink
060058

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Reported in μg/L (ppb)

RPD calculated using sample concentrations per SW846.

Volatile Surrogate Recovery

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<tr>
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<td>104%</td>
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</table>
## Organics Analysis Data Sheet

### Sample ID: LCS-042208

**QC Report No:** MS53-Aspect Consulting

**Project:** Sound Transit U Link

**Date Sampled:** NA

**Date Received:** NA

**Sample Amount LCS:** 20.0 mL

**Purge Volume LCS:** 20.0 mL

**Sample LCS:** 20.0 mL

---

**Analyte**

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<th>Spike</th>
<th>LCS</th>
<th>Recovery</th>
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ORGANICS ANALYSIS DATA SHEET
Volatiles by Purge & Trap GC/MS-Method SW8260B
Sample ID: LCS-042208
LAB CONTROL SAMPLE

Lab Sample ID: LCS-042208
LIMS ID: 08-7959
Matrix: Water

QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link
060058

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<td>87.5%</td>
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<td>90.0%</td>
</tr>
</tbody>
</table>

Reported in µg/L (ppb)

RPD calculated using sample concentrations per SW846.
ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8421BMod
TPHG by Method NWTPHG
Page 1 of 1

Lab Sample ID: MB-041908
LIMS ID: 08-7959
Matrix: Water
Data Release Authorized: 04/21/08
Date Analyzed: 04/19/08 11:30
Instrument/Analyst: PID3/PKC

<table>
<thead>
<tr>
<th>CAS Number</th>
<th>Analyte</th>
<th>RL</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>71-43-2</td>
<td>Benzene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>108-88-3</td>
<td>Toluene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>100-41-4</td>
<td>Ethylbenzene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>m,p-Xylene</td>
<td></td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>95-47-6</td>
<td>o-Xylene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
</tbody>
</table>

Purge Volume: 5.0 mL
Dilution Factor: 1.00

Gasoline Range Hydrocarbons
0.25 < 0.25 U ---

BETX Surrogate Recovery

Trifluorotoluene 91.7%
Bromobenzene     92.0%

Gasoline Surrogate Recovery

Trifluorotoluene 93.2%
Bromobenzene     94.5%

BETX values reported in µg/L (ppb)  
Gasoline values reported in mg/L (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.

Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.
ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod
TPHG by Method NWTPHG
Page 1 of 1

Lab Sample ID: MS53F
LIMS ID: 08-7959
Matrix: Water
Data Release Authorized: 04/21/08

Date Analyzed: 04/19/08 12:13
Instrument/Analyst: PID3/PKC

QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link
Event: 060058
Date Sampled: 04/15/08
Date Received: 04/16/08

Purge Volume: 5.0 mL
Dilution Factor: 1.00

<table>
<thead>
<tr>
<th>CAS Number</th>
<th>Analyte</th>
<th>RL</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>71-43-2</td>
<td>Benzene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>108-88-3</td>
<td>Toluene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>100-41-4</td>
<td>Ethylbenzene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>m,p-Xylene</td>
<td></td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
<tr>
<td>95-47-6</td>
<td>o-Xylene</td>
<td>1.0</td>
<td>&lt; 1.0 U</td>
</tr>
</tbody>
</table>

Gasoline Range Hydrocarbons 0.25 < 0.25 U ---

BETX Surrogate Recovery

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Recovery</th>
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</thead>
<tbody>
<tr>
<td>Trifluorotoluene</td>
<td>102%</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>99.3%</td>
</tr>
</tbody>
</table>

Gasoline Surrogate Recovery

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifluorotoluene</td>
<td>104%</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>101%</td>
</tr>
</tbody>
</table>

BETX values reported in μg/L (ppb)
Gasoline values reported in mg/L (ppm)

GAS: Indicates the presence of gasoline or weathered gasoline.
GRO: Positive result that does not match an identifiable gasoline pattern.
Quantitation on total peaks in the gasoline range from Toluene to Naphthalene.
**Sample ID:** LCS-041908  
**LAB CONTROL SAMPLE**

<table>
<thead>
<tr>
<th>QC Report No.</th>
<th>MS53-Aspect Consulting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project</td>
<td>Sound Transit U Link</td>
</tr>
<tr>
<td>Event</td>
<td>060058</td>
</tr>
<tr>
<td>Date Sampled</td>
<td>NA</td>
</tr>
<tr>
<td>Date Received</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Purge Volume:** 5.0 mL  
**Dilution Factor LCS:** 1.0  
**LCSD:** 1.0

**Date Analyzed LCS:** 04/19/08 10:41  
**LCSD:** 04/19/08 11:06

**Instrument/Analyst LCS:** PID3/PKC  
**LCSD:** PID3/PKC

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Spike LCS</th>
<th>Added-LCS</th>
<th>LCS Recovery</th>
<th>Spike LCSD</th>
<th>Added-LCSD</th>
<th>LCSD Recovery</th>
<th>RPD</th>
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<tbody>
<tr>
<td>Gasoline Range Hydrocarbons</td>
<td>0.98</td>
<td>1.00</td>
<td>98.0%</td>
<td>0.99</td>
<td>1.00</td>
<td>99.0%</td>
<td>1.0%</td>
</tr>
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</table>

Reported in mg/L (ppm)

RPD calculated using sample concentrations per SW846.

**TPHG Surrogate Recovery**

<table>
<thead>
<tr>
<th>Surrogate</th>
<th>LCS</th>
<th>LCSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifluorotoluene</td>
<td>94.9%</td>
<td>100%</td>
</tr>
<tr>
<td>Bromobenzene</td>
<td>96.5%</td>
<td>101%</td>
</tr>
</tbody>
</table>
ORGANICS ANALYSIS DATA SHEET
BETX by Method SW8021BMod

Sample ID: LCS-041908
LAB CONTROL SAMPLE

QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link
Event: 060058
Date Sampled: NA
Date Received: NA

Purge Volume: 5.0 mL
Dilution Factor LCS: 1.0
LCSD: 1.0

Date Analyzed LCS: 04/19/08 10:41
LCSD: 04/19/08 11:06
Instrument/Analyst LCS: PID3/PKC
LCSD: PID3/PKC

Reported in µg/L (ppb)

RPD calculated using sample concentrations per SW846.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>LCS</th>
<th>Spike Added-LCS</th>
<th>LCS Recovery</th>
<th>LCSD</th>
<th>Spike Added-LCSD</th>
<th>LCSD Recovery</th>
<th>RPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>7.10</td>
<td>7.00</td>
<td>101%</td>
<td>7.12</td>
<td>7.00</td>
<td>102%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Toluene</td>
<td>62.3</td>
<td>62.0</td>
<td>100%</td>
<td>62.0</td>
<td>62.0</td>
<td>100%</td>
<td>0.5%</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>11.4</td>
<td>11.9</td>
<td>95.8%</td>
<td>11.3</td>
<td>11.9</td>
<td>95.0%</td>
<td>0.9%</td>
</tr>
<tr>
<td>m,p-Xylene</td>
<td>44.0</td>
<td>44.6</td>
<td>98.7%</td>
<td>43.5</td>
<td>44.6</td>
<td>97.5%</td>
<td>1.1%</td>
</tr>
<tr>
<td>o-Xylene</td>
<td>15.7</td>
<td>15.8</td>
<td>99.4%</td>
<td>15.6</td>
<td>15.8</td>
<td>98.7%</td>
<td>0.6%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BETX Surrogate Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifluorotoluene</td>
</tr>
<tr>
<td>Bromobenzene</td>
</tr>
</tbody>
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Data file 1: /chem3/pid3.i/20080419-2.b/0419a007.d  
Data file 2: /chem3/pid3.i/20080419-1.b/0419a007.d  
Method: /chem3/pid3.i/20080419-1.b/PIDB.m  
Instrument: pid3.i  
Gas Ical Date: 18-APR-2008  
BETX Ical Date: 18-APR-2008  

ARID: mS53f  
Client ID: UL-551-041508  
Injection Date: 19-APR-2008 12:13  
Matrix: WATER  
Dilution Factor: 1.000

FID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Height</th>
<th>Area</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.957</td>
<td>0.008</td>
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<td>13.652</td>
<td>0.007</td>
<td>3898</td>
<td>45171</td>
<td>101.4</td>
<td>BB(Surr)</td>
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</table>

Petroleum Hydrocarbons (FID)

<table>
<thead>
<tr>
<th>Range</th>
<th>Total Area*</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAGas (Tol-C12)</td>
<td>5009</td>
<td>0.005</td>
</tr>
<tr>
<td>8015B (2MP-TMB)</td>
<td>3516</td>
<td>0.002</td>
</tr>
<tr>
<td>AKGas (nC6-nC10)</td>
<td>2300</td>
<td>0.002</td>
</tr>
<tr>
<td>NWGas (Tol-Nap)</td>
<td>7439</td>
<td>0.007</td>
</tr>
</tbody>
</table>

* Surrogate areas are subtracted from Total Area

PID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Response</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.956</td>
<td>0.009</td>
<td>32347</td>
<td>102.3</td>
<td>TFT(Surr)</td>
</tr>
<tr>
<td>13.650</td>
<td>0.007</td>
<td>53364</td>
<td>99.3</td>
<td>BB(Surr)</td>
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</table>

AROMATICS (PID)

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Response</th>
<th>Amount</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>Benzene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>Toluene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
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</tr>
<tr>
<td>11.371</td>
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<td>M/P-Xylene</td>
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<tr>
<td>ND</td>
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<td>---</td>
<td>---</td>
<td>O-Xylene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>MTBE</td>
</tr>
</tbody>
</table>

A Indicates Peak Area was used for quantitation instead of Height  
N Indicates peak peak was manually integrated
### FID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Height</th>
<th>Area</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.947</td>
<td>-0.002</td>
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<td>94664</td>
<td>93.2</td>
<td>TPT(Surr)</td>
</tr>
<tr>
<td>13.642</td>
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<td>3634</td>
<td>41064</td>
<td>94.5</td>
<td>BB(Surr)</td>
</tr>
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### PETROLEUM HYDROCARBONS (FID)

<table>
<thead>
<tr>
<th>Range</th>
<th>Total Area*</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAGas (Tol-C12)</td>
<td>3988</td>
<td>0.004</td>
</tr>
<tr>
<td>8015B (2MP-TMB)</td>
<td>4999</td>
<td>0.002</td>
</tr>
<tr>
<td>AKGas (nC6-nC10)</td>
<td>2127</td>
<td>0.001</td>
</tr>
<tr>
<td>NWGas (Tol-Nap)</td>
<td>5045</td>
<td>0.005</td>
</tr>
</tbody>
</table>

* Surrogate areas are subtracted from Total Area

### PID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Response</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.001</td>
<td>28971</td>
<td>91.7</td>
<td>TPT(Surr)</td>
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<tr>
<td>13.641</td>
<td>-0.002</td>
<td>49473</td>
<td>92.0</td>
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</tbody>
</table>

### AROMATICS (PID)

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Response</th>
<th>Amount</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>Benzene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>Toluene</td>
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<tr>
<td>ND</td>
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<td>---</td>
<td>---</td>
<td>Ethylbenzene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>M/P-Xylene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>O-Xylene</td>
</tr>
<tr>
<td>ND</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>MTBE</td>
</tr>
</tbody>
</table>

\ Indicates Peak Area was used for quantitation instead of Height
\ Indicates peak peak was manually integrated
Analytical Resources Inc.
BETX/Gas Quantitation Report

Data file 1: /chem3/pid3.i/20080419-2.b/0419a004.d
Data file 2: /chem3/pid3.i/20080419-1.b/0419a004.d
Method: /chem3/pid3.i/20080419-1.b/PIDB.m
Instrument: pid3.i
Gas Ical Date: 18-APR-2008
BETX Ical Date: 18-APR-2008

ARI ID: lcs041908s1
Client ID: 
Injection Date: 19-APR-2008 10:41
Matrix: WATER
Dilution Factor: 1.000

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### FID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
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<th>Area</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.947</td>
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<td>7545</td>
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<tr>
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<td>3710</td>
<td>42854</td>
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<td>BB(Surr)</td>
</tr>
</tbody>
</table>

### PETROLEUM HYDROCARBONS (FID)

<table>
<thead>
<tr>
<th>Range</th>
<th>Total Area*</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAGas (Tol-C12)</td>
<td>976458</td>
<td>0.975</td>
</tr>
<tr>
<td>8015B (2MP-TMB)</td>
<td>2112680</td>
<td>1.023</td>
</tr>
<tr>
<td>AKGas (nC6-nC10)</td>
<td>1465519</td>
<td>1.013</td>
</tr>
<tr>
<td>NWGas (Tol-Nap)</td>
<td>1030502</td>
<td>0.981</td>
</tr>
</tbody>
</table>

* Surrogate areas are subtracted from Total Area

---

### PID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Response</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-0.001</td>
<td>29854</td>
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### AROMATICS (PID)

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<tr>
<th>RT</th>
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<th>Response</th>
<th>Amount</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
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<td>62.32</td>
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<td>11.221</td>
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<td>19793</td>
<td>11.42</td>
<td>Ethylbenzene</td>
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<td>11.360</td>
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<td>M/P-Xylene</td>
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<td>12.149</td>
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<td>O-Xylene</td>
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<td>4.044</td>
<td>0.003</td>
<td>46228</td>
<td>88.30</td>
<td>MTBE</td>
</tr>
</tbody>
</table>

\* Indicates Peak Area was used for quantitation instead of Height
\d Indicates peak peak was manually integrated
Analytical Resources Inc.
BETX/Gas Quantitation Report

Data file 1: /chem3/pid3.i/20080419-2.b/0419a005.d
Data file 2: /chem3/pid3.i/20080419-1.b/0419a005.d
Method: /chem3/pid3.i/20080419-1.b/PIDB.m
Instrument: pid3.i
Gas Ical Date: 18-APR-2008
BETX Ical Date: 18-APR-2008

ARI ID: lcsd041908s1
Client ID: Injection Date: 19-APR-2008 11:06
Matrix: WATER
Dilution Factor: 1.000

==================================================

FID Surrogates

<table>
<thead>
<tr>
<th>RT</th>
<th>Shift</th>
<th>Height</th>
<th>Area</th>
<th>%Rec</th>
<th>Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.946</td>
<td>-0.003</td>
<td>7950</td>
<td>105646</td>
<td>100.0</td>
<td>TFT(Surr)</td>
</tr>
<tr>
<td>13.643</td>
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<td>44626</td>
<td>100.7</td>
<td>BB(Surr)</td>
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PETROLEUM HYDROCARBONS (FID)

<table>
<thead>
<tr>
<th>Range</th>
<th>Total Area*</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>WAGas (Tol-C12)</td>
<td>983200</td>
<td>0.982</td>
</tr>
<tr>
<td>8015B (2MP-TMB)</td>
<td>2168054</td>
<td>1.049</td>
</tr>
<tr>
<td>AKGas (nC6-nC10)</td>
<td>1487374</td>
<td>1.028</td>
</tr>
<tr>
<td>NWGas (Tol-Nap)</td>
<td>1038052</td>
<td>0.988</td>
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* Surrogate areas are subtracted from Total Area

==================================================

PID Surrogates

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AROMATICS (PID)

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\ Indicates Peak Area was used for quantitation instead of Height
\ Indicates peak was manually integrated
ORGANICS ANALYSIS DATA SHEET
METHANE ETHANE ETHENE

QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link
060058
Date Received: 04/16/08

Data Release Authorized: ✔
Reported: 04/28/08

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Reported in ug/L (ppb)
ORGANICS ANALYSIS DATA SHEET
TOTAL DIESEL RANGE HYDROCARBONS
NWTPHD by GC/FID
Matrix: Water

Data Release Authorized: 
Reported: 04/24/08

QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link
060058
Date Received: 04/16/08

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Reported in mg/L (ppm)

EFV-Effective Final Volume in mL.
DL-Dilution of extract prior to analysis.
RL-Reporting limit.

Diesel quantitation on total peaks in the range from C12 to C24.
Motor Oil quantitation on total peaks in the range from C24 to C38.
HC ID: DRO/RRO indicates results of organics or additional hydrocarbons in ranges are not identifiable.
ORGANICS ANALYSIS DATA SHEET

NWTPHD by GC/FID

Sample ID: LCS-042108
LAB CONTROL

QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link
060058
Date Sampled: NA
Date Received: NA

Sample Amount: 500 mL
Final Extract Volume: 1.0 mL
Dilution Factor: 1.00

Lab Spike Recovery
Control Added

Range

Diesel 2.24 3.00 74.7%

TPHD Surrogate Recovery

o-Terphenyl 88.0%

Results reported in mg/L

FORM III
## FID:3A RESULTS

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<tr>
<th>Compound</th>
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<th>Total Area</th>
<th>Conc</th>
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### Surrogate

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### Analyte

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Client ID: 
Injection: 21-APR-2008 23:51
dilution factor: 1
### FID.3A RESULTS

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### Range Times:
- NW Diesel (3.046 - 5.278)
- NW Gas (1.754 - 3.046)
- NW M.Oil (5.278 - 7.229)
- AK102 (2.463 - 5.309)
- AK103 (5.309 - 6.788)
- Jet A (2.463 - 4.203)

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# Analytical Resources Inc.
## TPH Quantitation Report

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ARI ID: MS53F  
Method: /chem3/fid3a.i/20080421.b/fidphf3a.m  
Client ID:  
Instrument: fid3a.i  
Injection: 22-APR-2008 00:52  
Operator: JR  
Dilution Factor: 1  
Report Date: 04/23/2008  
Macro: FID:3A041608

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**Range Times:** NW Diesel(3.046 - 5.278) NW Gas(1.754 - 3.046) NW M.Oil(5.278 - 7.229) AK102(2.463 - 5.309) AK103(5.309 - 6.788) Jet A(2.463 - 4.203)

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Data Release Authorized:  
Reported: 04/28/08

Project: Sound Transit U Link  
Event: 060058  
Date Sampled: 04/15/08  
Date Received: 04/16/08

Client ID: UL-551-041508  
ARI ID: 08-7959 MS53F

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RL       Analytical reporting limit  
U        Undetected at reported detection limit

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### INORGANICS ANALYSIS DATA SHEET

**TOTAL METALS**

**Sample ID: METHOD BLANK**

**Lab Sample ID:** MS53MB  
**LIMS ID:** 08-7959  
**Matrix:** Water  
**Data Release Authorized:**  
**Reported:** 04/28/08

**QC Report No:** MS53-Aspect Consulting  
**Project:** Sound Transit U Link  
**060058**  
**Date Sampled:** NA  
**Date Received:** NA

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- U-Analyte undetected at given RL
- RL-Reporting Limit
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**Calculated Hardness (mg-CaCO3/L):** 50

*U-Analyte undetected at given RL*

*RL-Reporting Limit*
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Reported in μg/L

N-Control limit not met
Control Limits: 80-120%
INORGANICS ANALYSIS DATA SHEET
Dissolved Metals

Sample ID: METHOD BLANK
QC Report No: MS53-Aspect Consulting
Project: Sound Transit U Link 060058

Date Sampled: NA
Date Received: NA

Lab Sample ID: MS53MB
LIMS ID: 08-7961
Matrix: Water
Data Release Authorized: NA
Reported: 04/28/08

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U-Analyte undetected at given RL
RL-Reporting Limit
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U-Analyte undetected at given RL
RL-Reporting Limit
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Reported in µg/L

N=Control limit not met
Control Limits: 80-120%
Particle Size Distribution Report

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**Cobbles**

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**USC Classification**

- Silty gravel with sand
- Silty sand
- Silty sand

**Remarks**

- Classification based on grain size only
- Classification based on grain size only
- Classification based on grain size only

**Sound Transit**

**Client:** Sound Transit

**Project:** University Link Project RTA/LR 8-06

**Project No.:** J-07-2195

**Figure:** 27

**SOIL TECHNOLOGY**

**Bainbridge Island, WA**

**Tested By:** AJA  RMD  RMD  Checked By: RGS
### Particle Size Distribution Report

**USC Classification**
- ○ silty sand

**Remarks:**
- ○ Classification based on grain size only

**Source of Sample:** UL-551
- Depth: 135.0 - 135.8
- Sample Number: SS-12

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</table>

**SIEVE inches size PERCENT FINER**
- 0.5 100.0
- 0.375 99.1

**SIEVE number size PERCENT FINER**
- #4 98.3
- #10 97.6
- #20 95.4
- #40 82.7
- #60 46.3
- #140 19.9
- #200 17.0

**Classification based on grain size only**

<table>
<thead>
<tr>
<th>Cobble</th>
<th>% GRAVEL</th>
<th>% SAND</th>
<th>% SILT</th>
<th>% CLAY</th>
<th>USCS</th>
<th>AASHTO</th>
<th>PL</th>
<th>LL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.7</td>
<td>81.3</td>
<td></td>
<td>17.0</td>
<td>SM</td>
<td>A-2-4(0)</td>
<td>NP</td>
<td>NV</td>
</tr>
</tbody>
</table>

**Client:** Sound Transit
**Project:** University Link Project RTA/LR 8-06
**Project No.:** J-07-2195

**Tested By:** RMD
**Checked By:** RGS
Atterberg Limits Test Report (ASTM D-4318)

Dashed line indicates the approximate upper limit boundary for natural soils.

SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>UL-552</td>
<td>CC-5</td>
<td>46.0-47.0</td>
<td>18.5</td>
<td>NP</td>
<td>GNP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NP/GNP = Granular Non-Plastic
UL-553
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th>Monitoring Well</th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL-553W</td>
<td>68.0</td>
<td>--</td>
<td>18.5</td>
<td>28.5</td>
<td>31.40 11/20/07 10:30</td>
<td>31.19 07/01/08 11:35</td>
</tr>
</tbody>
</table>
### Particle Size Distribution Report

<table>
<thead>
<tr>
<th>GRAIN SIZE - MM</th>
<th>PERCENT FINER</th>
<th>PERCENT COARSER</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in.</td>
<td>10.0</td>
<td>100.0</td>
</tr>
<tr>
<td>3 in.</td>
<td>88.6</td>
<td>11.4</td>
</tr>
<tr>
<td>2 1/2 in.</td>
<td>71.1</td>
<td>28.9</td>
</tr>
<tr>
<td>1 1/2 in.</td>
<td>64.9</td>
<td>35.1</td>
</tr>
<tr>
<td>1 in.</td>
<td>50.0</td>
<td>50.0</td>
</tr>
<tr>
<td>¾ in.</td>
<td>38.5</td>
<td>61.5</td>
</tr>
<tr>
<td>½ in.</td>
<td>25.0</td>
<td>75.0</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>18.0</td>
<td>82.0</td>
</tr>
<tr>
<td>#4</td>
<td>10.0</td>
<td>90.0</td>
</tr>
<tr>
<td>#10</td>
<td>6.2</td>
<td>93.8</td>
</tr>
<tr>
<td>#20</td>
<td>3.6</td>
<td>96.4</td>
</tr>
<tr>
<td>#30</td>
<td>2.0</td>
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<tr>
<td>#40</td>
<td>1.0</td>
<td>99.0</td>
</tr>
<tr>
<td>#60</td>
<td>0.5</td>
<td>99.5</td>
</tr>
<tr>
<td>#100</td>
<td>0.2</td>
<td>99.8</td>
</tr>
<tr>
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<td>99.9</td>
</tr>
<tr>
<td>#200</td>
<td>0.01</td>
<td>99.99</td>
</tr>
</tbody>
</table>

#### USC Classification
- Silty sand
- Poorly graded sand with gravel

#### Remarks:

- Source of Sample: UL-553
- Depth: 25.0-26.0
- Sample Number: CC-5
- Source of Sample: UL-553
- Depth: 39.0-40.0
- Sample Number: CC-7

#### Soil Technology

Bainbridge Island, WA

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195
UL-555
### Particle Size Distribution Report

#### GRAIN SIZE - MM

<table>
<thead>
<tr>
<th>GRAIN SIZE</th>
<th>PERCENT FINER</th>
<th>COEFFICIENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in.</td>
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<td>0.001</td>
</tr>
<tr>
<td>3 in.</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>2 in.</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>1 in.</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>¾ in.</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>½ in.</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>0.010</td>
<td>0.010</td>
</tr>
<tr>
<td>#4</td>
<td>0.010</td>
<td>0.010</td>
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<td>0.010</td>
</tr>
<tr>
<td>#200</td>
<td>0.010</td>
<td>0.010</td>
</tr>
</tbody>
</table>

#### Source of Sample:
- UL-555
- Depth: 4.0-5.0
- Sample Number: CC-1
- Depth: 17.0-18.0
- Sample Number: CC-2
- Depth: 31.0-32.0
- Sample Number: CC-4

### USCS Classification
- Silty sand with gravel
- Silty sand with gravel
- Silty sand with gravel

### Remarks:
- Client: Sound Transit
- Project: University Link Project RTA/LR 8-06
- Project No.: J-07-2195
- Figure: 31

### Soil Technology
Bainbridge Island, WA
**Particle Size Distribution Report**

- **Source of Sample:** UL-555  
  Depth: 52.0-53.0  
  Sample Number: CC-6

- **Source of Sample:** UL-555  
  Depth: 64.0-65.0  
  Sample Number: CC-7

**Cobbles**  
- % GRAVEL: 48.9  
- % SAND: 44.5  
- % SILT: 6.6  
- USCS: GP-GM  
- AASHTO: A-1-b  
- PL: NP  
- LL: NV

**Cobbles**  
- % GRAVEL: 50.8  
- % SAND: 45.0  
- % SILT: 4.2  
- USCS: GW  
- AASHTO: A-1-a  
- PL: NP  
- LL: NV

**USC Classification**  
- Poorly graded gravel with silt and sand
- Well-graded gravel with sand

**REMARKS:**

- ○
- □

**GRAIN SIZE - MM**

<table>
<thead>
<tr>
<th>SIEVE number size</th>
<th>PERCENT FINER</th>
<th>SIEVE number size</th>
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<td>#40</td>
<td>19.8</td>
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<td>17.1</td>
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<tr>
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<td>8.4</td>
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**PERCENT FINER**

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<tr>
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<tr>
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<td>10</td>
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</table>

**PERCENT FINER**

<table>
<thead>
<tr>
<th>PERCENT COARSER</th>
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<tbody>
<tr>
<td>100</td>
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<tr>
<td>90</td>
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<td>20</td>
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**GRAIN SIZE**

<table>
<thead>
<tr>
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<td>0.001</td>
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<td>48.000</td>
</tr>
<tr>
<td>96.000</td>
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<tr>
<td>192.000</td>
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**COEFFICIENTS**

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<th>VALUE</th>
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<td>0.16</td>
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<tr>
<td>Cu</td>
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</table>

**SOIL TECHNOLOGY**

**Bainbridge Island, WA**

**Client:** Sound Transit  
**Project:** University Link Project RTA/LR 8-06  
**Project No.:** J-07-2195  
**Figure:** 32
Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

<table>
<thead>
<tr>
<th></th>
<th>Ground Surface Elevation (ft)</th>
<th>VWP Elevation (ft)</th>
<th>Screen Int. Top Elev. (ft)</th>
<th>Screen Int. Bottom Elev. (ft)</th>
<th>Maximum Water Level Elevation (ft)</th>
<th>Minimum Water Level Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>UL-556W</td>
<td>82.6</td>
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<td>32.1</td>
<td>42.1</td>
<td>33.02 03/27/08 09:45</td>
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</table>
Particle Size Distribution Report

<table>
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<th>SIEVE</th>
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<th>PERCENT FINER</th>
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</thead>
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<td>inches size</td>
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<td>0.1867</td>
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<td></td>
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<tr>
<td>.375 in.</td>
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<table>
<thead>
<tr>
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<td>#10</td>
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<td>#20</td>
<td>60.4</td>
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<tr>
<td>#40</td>
<td>52.7</td>
</tr>
<tr>
<td>#60</td>
<td>38.9</td>
</tr>
<tr>
<td>#140</td>
<td>17.2</td>
</tr>
<tr>
<td>#200</td>
<td>13.1</td>
</tr>
</tbody>
</table>

USCS Classification
- silty sand with gravel
- poorly graded sand

Remarks:
- Source of Sample: UL-556 Depth: 21.0-22.0 Sample Number: CC-3
- Source of Sample: UL-556 Depth: 40.0-41-0 Sample Number: CC-5

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

SOIL TECHNOLOGY
Bainbridge Island, WA
UL-557
### SOIL TECHNOLOGY

#### Bainbridge Island, WA

---

**Particle Size Distribution Report**

**USC Classification**
- ○ silty sand with gravel
- □ poorly graded sand with silt
- △ silty sand with gravel

**Remarks:**
- ○
- □
- △

**Cobbles**

<table>
<thead>
<tr>
<th>GRAIN SIZE - MM</th>
<th>PERCENT FINER</th>
<th>PERCENT COARSER</th>
</tr>
</thead>
<tbody>
<tr>
<td>% GRAVEL</td>
<td>% SAND</td>
<td>% SILT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>□ 0.0</td>
<td>27.2</td>
<td>49.3</td>
</tr>
<tr>
<td>□ 0.0</td>
<td>0.0</td>
<td>93.8</td>
</tr>
<tr>
<td>□ 0.0</td>
<td>35.0</td>
<td>47.3</td>
</tr>
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</table>

**GRAIN SIZE**

<table>
<thead>
<tr>
<th>SIEVE size</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 in.</td>
<td>100.0</td>
</tr>
<tr>
<td>3 in.</td>
<td></td>
</tr>
<tr>
<td>2 in.</td>
<td></td>
</tr>
<tr>
<td>1½ in.</td>
<td></td>
</tr>
<tr>
<td>1 in.</td>
<td></td>
</tr>
<tr>
<td>¾ in.</td>
<td>86.7</td>
</tr>
<tr>
<td>½ in.</td>
<td>84.4</td>
</tr>
<tr>
<td>3/8 in.</td>
<td>78.6</td>
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**COEFFICIENTS**

<table>
<thead>
<tr>
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<tr>
<td>Cu</td>
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**Source of Sample:**
- ○ Source of Sample: UL-557 Depth: 8.0-9.0 Sample Number: CC-1
- □ Source of Sample: UL-557 Depth: 30.0-31.0 Sample Number: CC-4
- △ Source of Sample: UL-557 Depth: 20.0-21.0 Sample Number: CC-3

**Client:** Sound Transit  
**Project:** University Link Project RTA/LR 8-06  
**Project No.:** J-07-2195  
**Figure:** 34
SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>UL-557</td>
<td>CC-7</td>
<td>44.0-45.0</td>
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<td>NP</td>
<td>GNP</td>
<td>ML</td>
<td></td>
</tr>
</tbody>
</table>

NP/GNP = Granular Non-Plastic

Dashed line indicates the approximate upper limit boundary for natural soils.
Particle Size Distribution Report

Cobbles  % GRAVEL  % SAND  % SILT  % CLAY  USCS  AASHTO  PL  LL
0.0  0.0  47.8  52.2  ML  A-4(0)  NP  NV
0.0  14.4  73.6  12.0  SP-SM  A-2-4(0)  NP  NV

SIEVE inches size  PERCENT FINER
1  100.0
.75  97.7
.5  95.0
.375  93.6

SIEVE number size  PERCENT FINER
#4  85.6
#10  77.5
#20  68.6
#40  54.4
#60  31.9
#140  13.8
#200  12.0

USC Classification
○ sandy silt
□ poorly graded sand with silt

REMARKS:

D₆₀  0.0898  D₃₀  0.5111  D₁₀  0.2378

Cₐ  Cₜ

Source of Sample: UL-558  Depth: 33.0-34.0  Sample Number: CC-4
Source of Sample: UL-558  Depth: 53.0-54.0  Sample Number: CC-5

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

SOIL TECHNOLOGY
Bainbridge Island, WA

Figure 35
Dashed line indicates the approximate upper limit boundary for natural soils.
Particle Size Distribution Report

Cobbles % GRAVEL % SAND % SILT % CLAY USCS AASHTO PL LL
0.0 0.0 15.5 84.5 ML A-4(0) NP NV
0.0 24.8 51.8 23.4 SM A-2-4(0) NP NV

USC Classification
○ silt with sand
□ silty sand with gravel

Source of Sample: UL-559 Depth: 46.0-47.0 Sample Number: CC-6
□ Source of Sample: UL-559 Depth: 80.0-82.0 Sample Number: CC-9

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195
**SOIL DATA**

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
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<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>•</td>
<td>UL-559</td>
<td>CC-7</td>
<td>55-56</td>
<td>18.4</td>
<td>NP</td>
<td>NV</td>
<td>NP</td>
<td>ML</td>
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<td>•</td>
<td>UL-559</td>
<td>CC-9</td>
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<td>27.9</td>
<td>25</td>
<td>53</td>
<td>28</td>
<td>CH</td>
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</table>

Dashed line indicates the approximate upper limit boundary for natural soils.

**Atterberg Limits Test Report (ASTM D-4318)**

SOIL TECHNOLOGY

Bainbridge Island, WA

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

Tested By: AJA
Checked By: RGS
<table>
<thead>
<tr>
<th>Date</th>
<th>Water Level Elevation (ft)</th>
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<tbody>
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Water levels on hydrograph are daily averages. Minimum and maximum levels (and corresponding date/time) are specific measurements and not averages.

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<td>34.8</td>
<td>35.9</td>
</tr>
</tbody>
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UL-560
VWP (Slope Indicator)
Particle Size Distribution Report

Cobbles | % GRAVEL | % SAND | % SILT | % CLAY | USCS | AASHTO | PL | LL
0.0 | 26.2 | 51.7 | 22.1 | SM | A-2-4(0) | NP | NV
0.0 | 47.3 | 49.0 | 3.7 | SP | A-1-b | NP | NV
0.0 | 44.6 | 42.8 | 12.6 | GM | A-1-b | NP | NV

Source of Sample: UL-560
Depth: 21.0-22.0
Sample Number: CC-3

Source of Sample: UL-560
Depth: 40.0-41.0
Sample Number: CC-7

Source of Sample: UL-560
Depth: 52.0-54.0
Sample Number: CC-8

USC Classification
- silty sand with gravel
- poorly graded sand with gravel
- silty gravel with sand

Remarks:

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

SOIL TECHNOLOGY
Bainbridge Island, WA
# Particle Size Distribution Report

### Source of Sample:
- UL-560
- Depth: 70.0-71.0
- Sample Number: CC-10

### Source of Sample:
- UL-560
- Depth: 95.0-96.0
- Sample Number: CC-12

### GRAIN SIZE - MM

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<tr>
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<table>
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<tr>
<th>PERCENT COARSER</th>
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<tbody>
<tr>
<td>100</td>
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</tbody>
</table>

### Particle Size Distribution Chart

- **Cobbles:** 0.0%
- **% GRAVEL:** 4.1%
- **% SAND:** 93.8%
- **% SILT:** 2.1%
- **% CLAY:** SP
- **USCS:** A-3
- **AASHTO:** NP
- **PL:** NV
- **LL:** NV

<table>
<thead>
<tr>
<th>SIEVE</th>
<th>PERCENT FINER</th>
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<tr>
<td>6 in.</td>
<td>3 in.</td>
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<td>0.001</td>
<td>0.01</td>
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<tr>
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<td>98.9</td>
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### USC Classification
- **Cobbles:** # poorly graded sand

### GRAN SIZE

<table>
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<tr>
<td>D60</td>
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### COEFFICIENTS

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<tr>
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### Remarks:
- Source of Sample: UL-560
- Depth: 70.0-71.0
- Sample Number: CC-10
- Source of Sample: UL-560
- Depth: 95.0-96.0
- Sample Number: CC-12

### Client:
- Sound Transit

### Project:
- University Link Project RTA/LR 8-06

### Project No.:
- J-07-2195

### Figure:
- 38
### Atterberg Limits Test Report (ASTM D-4318)

Dashed line indicates the approximate upper limit boundary for natural soils.

#### SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
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<tr>
<td>·</td>
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<td>CC-13</td>
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**SOIL TECHNOLOGY**

Bainbridge Island, WA

**Client:** Sound Transit  
**Project:** University Link Project RTA/LR 8-06  
**Project No.:** J-07-2195  
**Figure:** 50

Tested By: AJA
### Particle Size Distribution Report

#### COEFFICIENTS
- $C_C = 0.15$ 0.15 1.00
- $C_u = 79.42$ 2.22 2.30

#### GRAIN SIZE
- $D_{60} = 0.2014$ 0.3990 0.3100
- $D_{30} = 0.6271$ 0.2877 0.2043
- $D_{10} = 0.1789$ 0.1798 0.1346

#### SIEVE INCHES SIZE
- 6 in. 3 in. 2 in. 1 1/2 in. 1 in. 3/4 in. 1/2 in. 3/8 in. #4 #10 #20 #30 #40 #60 #100 #140 #200

#### PERCENT FINER
- 0 10 20 30 40 50 60 70 80 90 100

#### USC Classification
- ○ poorly graded gravel with sand
- □ poorly graded sand
- △ poorly graded sand

#### REMARKS:
- Source of Sample: UL-561 Depth: 31.0-32.0 Sample Number: CC-5
- Source of Sample: UL-561 Depth: 60.0-61.0 Sample Number: CC-7
- Source of Sample: UL-561 Depth: 85.0-86.0 Sample Number: CC-9

#### Client:
- Sound Transit

#### Project:
- University Link Project RTA/LR 8-06

#### Project No.:
- J-07-2195

#### Soil Technology
- Bainbridge Island, WA
### Particle Size Distribution Report

#### GRAIN SIZE - MM

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<tr>
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#### PERCENT FINER

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#### COEFFICIENTS

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<td>D₁₀</td>
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#### Source of Sample: UL-561

### REMARKS:

- Poorly graded sand

---

**Client:** Sound Transit  
**Project:** University Link Project RTA/LR 8-06  
**Project No.:** J-07-2195  
**Figure:** 40
Atterberg Limits Test Report (ASTM D-4318)

SOIL DATA

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<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
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<th>NATURAL WATER CONTENT (%)</th>
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<th>LIQUID LIMIT (%)</th>
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Dashed line indicates the approximate upper limit boundary for natural soils.
UL-562
Particle Size Distribution Report

Cobbles | % GRAVEL | % SAND | % SILT | % CLAY | USCS | AASHTO | PL | LL
--- | --- | --- | --- | --- | --- | --- | --- | ---
0.0  | 29.2 | 41.0 |  | 29.8 | SM | A-2-4(0) | NP | NV
0.0  | 0.0  | 65.9 |  | 34.1 | SM | A-2-4(0) | NP | NV
0.0  | 28.6 | 39.9 |  | 31.5 | SM | A-2-4(0) | NP | NV

SIEVE | PERCENT FINER | PERCENT COARSER | USC Classification
--- | --- | --- | ---
#4  | 70.8 | 100.0 | silty sand with gravel
#10 | 66.4 | 99.9 | silty sand
#20 | 61.8 | 99.9 | silty sand with gravel
#40 | 55.1 | 99.8 | silty sand
#60 | 45.1 | 96.7 | silty sand with gravel
#140| 32.7 | 46.0 | silty sand with gravel
#200| 29.8 | 34.1 |

GRAIN SIZE - MM

PERCENT FINER

PERCENT COARSER

0.001 0.01 0.1 1 10 100

0 10 20 30 40 50 60 70 80 90 100

0 0.01 0.1 1 10 100

GRAIN SIZE

D₆₀ 0.6564
D₃₀ 0.0765
D₁₀ 0.1344

COEFFICIENTS

Cc
Cu

Source of Sample: UL-562  Depth: 29.0-30.0  Sample Number: CC-3
Source of Sample: UL-562  Depth: 62.0-63.0  Sample Number: CC-7
Source of Sample: UL-562  Depth: 70.0-73.0  Sample Number: CC-8

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

SOIL TECHNOLOGY
Bainbridge Island, WA
Particle Size Distribution Report

Cobbles | % GRAVEL | % SAND | % SILT | % CLAY | USC | AASHTO | PL | LL
--- | --- | --- | --- | --- | --- | --- | --- | ---
0.0 | 0.0 | 96.4 | 3.6 | SP | A-3 | NP | NV
0.0 | 34.4 | 54.9 | 10.7 | SP-SM | A-1-b | NP | NV
0.0 | 10.9 | 88.6 | 0.5 | SP | A-3 | NP | NV

*Source of Sample: UL-562 Depth: 94.0-95.0 Sample Number: CC-9
*Source of Sample: UL-562 Depth: 108.0-109.0 Sample Number: CC-10
*Source of Sample: UL-562 Depth: 119.0-120.0 Sample Number: CC-10

USC Classification
-  ○ poorly graded sand
-  □ poorly graded sand with silt and gravel
-  △ poorly graded sand

Remarks:
-  ○
-  □
-  △

GRAN SIZE - MM

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<td>99.9</td>
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<tr>
<td>#40</td>
<td>97.0</td>
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<td>#60</td>
<td>70.2</td>
</tr>
<tr>
<td>#140</td>
<td>14.4</td>
</tr>
<tr>
<td>#200</td>
<td>3.6</td>
</tr>
</tbody>
</table>

D60 0.2159 2.7079 0.3056
D30 0.1410 0.2516 0.1955
D10 0.0941 0.1335

COEFFICIENTS
-  Cc 0.98 0.94
-  Cc 2.29 2.29

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

SOIL TECHNOLOGY
Bainbridge Island, WA

Graph showing particle size distribution with various sieves and percent finer values.
Atterberg Limits Test Report (ASTM D-4318)

SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>UL-562</td>
<td>CC-13</td>
<td>160.0-161.0</td>
<td>23.9</td>
<td>23</td>
<td>49</td>
<td>26</td>
<td>CL</td>
</tr>
</tbody>
</table>

Dashed line indicates the approximate upper limit boundary for natural soils.
UL-565
### Soil Technology

**Bainbridge Island, WA**

#### Particle Size Distribution Report

**GRAIN SIZE - MM**

<table>
<thead>
<tr>
<th>SIEVE number size</th>
<th>PERCENT FINER</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td>67.3</td>
<td>98.0</td>
</tr>
<tr>
<td>#10</td>
<td>60.2</td>
<td>96.7</td>
</tr>
<tr>
<td>#20</td>
<td>53.3</td>
<td>94.6</td>
</tr>
<tr>
<td>#40</td>
<td>42.9</td>
<td>91.4</td>
</tr>
<tr>
<td>#60</td>
<td>28.9</td>
<td>80.1</td>
</tr>
<tr>
<td>#140</td>
<td>15.3</td>
<td>34.9</td>
</tr>
<tr>
<td>#200</td>
<td>12.7</td>
<td>24.2</td>
</tr>
</tbody>
</table>

**USC Classification**

- Silty sand with gravel
  - USCS: SM
  - AASHTO: A-1-b
  - PL: NP
  - LL: NV

- Silty sand
  - USCS: SM
  - AASHTO: A-2-4(0)
  - PL: NP
  - LL: NV

- Poorly graded sand with silt
  - USCS: SP-SM
  - AASHTO: A-2-4(0)
  - PL: NP
  - LL: NV

**Remarks:**

- Source of Sample: UL-565
  - Depth: 12.0-13.0
  - Sample Number: CC-1

- Source of Sample: UL-565
  - Depth: 20.0-21.0
  - Sample Number: CC-3

- Source of Sample: UL-565
  - Depth: 70.0-71.0
  - Sample Number: CC-7

**Client:** Sound Transit

**Project:** University Link Project RTA/LR 8-06

**Project No.:** J-07-2195

**Figure:** 44
### Particle Size Distribution Report

#### Source of Sample: UL-565
- Depth: 46.0-47.0
- Sample Number: CC-5

#### Source of Sample: UL-565
- Depth: 93.0-94.0
- Sample Number: CC-8

#### Table: Grain Size Distribution

<table>
<thead>
<tr>
<th>GRAIN SIZE - MM</th>
<th>PERCENT COARSER</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>D₆₀</td>
<td>0.2437</td>
<td>0.2608</td>
</tr>
<tr>
<td>D₃₀</td>
<td>0.1253</td>
<td>0.1307</td>
</tr>
<tr>
<td>D₁₀</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Coefficients:
- Cc
- Cu

#### Remarks:
- Silty sand with gravel
- Silty sand

#### USC Classification:
- SMA-2-4(0)
- NPNV

#### Summary:
- Client: Sound Transit
- Project: University Link Project RTA/LR 8-06
- Project No.: J-07-2195

### Particle Size Distribution Chart

- **Sieves (inches):** 6 in., 3 in., 2 in., 1 ½ in., 1 in., ¾ in., ½ in., 3/8 in., #4, #10, #20, #40, #60, #140, #200
- **Percent Finer (USCS):**
  - 0.0: 100.0
  - 0.05: 97.6
  - 0.1: 96.9
  - 0.15: 96.2
  - 0.2: 94.3
  - 0.25: 91.0
  - 0.3: 87.0
  - 0.35: 84.0
  - 0.4: 80.2
  - 0.45: 76.5
  - 0.5: 72.7
  - 0.55: 68.9
  - 0.6: 65.0
  - 0.65: 61.0
  - 0.7: 57.1
  - 0.75: 53.2
  - 0.8: 49.3
  - 0.85: 45.4
  - 0.9: 41.5
  - 0.95: 37.6
  - 1.0: 33.7
  - 1.05: 29.8
  - 1.1: 25.9
  - 1.15: 22.0
  - 1.2: 18.1
  - 1.25: 14.2
  - 1.3: 10.3
  - 1.35: 6.4
  - 1.4: 2.5
  - 1.45: 0.6
  - 1.5: 0.1

#### Table: Source and Depth Information

- **Cobbles:** 0.0 % GRANUL, 19.8 % SAND, 62.1 % CLAY, 18.1 % CLAY
- **USCS:** A-2-4(0)
- **PL:** NP
- **LL:** NV

- **Depth:** 46.0-47.0
- **Sample Number:** CC-5

#### Remarks:
- Source of Sample: UL-565
- Depth: 46.0-47.0
- Sample Number: CC-5

#### Notes:
- Silty sand with gravel
### Soil Technology

**Bainbridge Island, WA**

#### Particle Size Distribution Report

**Source of Sample:** UL-565  
**Depth:** 112.0-113.0  
**Sample Number:** CC-9

- **Cobbles:** 0.0
- **% GRAVEL:** 52.5
- **% SAND:** 45.6
- **% SILT:** 19
- **% CLAY:** 1.9
- **USCS:** GP  
- **AASHTO:** A-1-a  
- **PL:** NP  
- **LL:** NV

- **Cobbles:** 0.0
- **% GRAVEL:** 6.3
- **% SAND:** 62.1
- **% SILT:** 31.6
- **% CLAY:** 1.9
- **USCS:** SM  
- **AASHTO:** A-2-4(0)  
- **PL:** NP  
- **LL:** NV

<table>
<thead>
<tr>
<th>GRAIN SIZE - MM</th>
<th>PERCENT FINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inches</td>
<td></td>
</tr>
<tr>
<td>6 in.</td>
<td></td>
</tr>
<tr>
<td>3 in.</td>
<td></td>
</tr>
<tr>
<td>2 in.</td>
<td></td>
</tr>
<tr>
<td>1½ in.</td>
<td></td>
</tr>
<tr>
<td>1 in.</td>
<td></td>
</tr>
<tr>
<td>¾ in.</td>
<td></td>
</tr>
<tr>
<td>½ in.</td>
<td></td>
</tr>
<tr>
<td>3/8 in.</td>
<td></td>
</tr>
<tr>
<td>#4</td>
<td></td>
</tr>
<tr>
<td>#10</td>
<td></td>
</tr>
<tr>
<td>#20</td>
<td></td>
</tr>
<tr>
<td>#40</td>
<td></td>
</tr>
<tr>
<td>#60</td>
<td></td>
</tr>
<tr>
<td>#140</td>
<td></td>
</tr>
<tr>
<td>#200</td>
<td></td>
</tr>
</tbody>
</table>

- **Cobbles:**
- **% GRAVEL:** 52.5
- **% SAND:** 45.6
- **% SILT:** 19
- **% CLAY:** 1.9
- **USCS:** GP
- **AASHTO:** A-1-a
- **PL:** NP
- **LL:** NV

- **Cobbles:**
- **% GRAVEL:** 6.3
- **% SAND:** 62.1
- **% SILT:** 31.6
- **% CLAY:** 1.9
- **USCS:** SM
- **AASHTO:** A-2-4(0)
- **PL:** NP
- **LL:** NV

**USC Classification:**
- poorly graded gravel with sand
- silty sand

**Remarks:**

- Source of Sample: UL-565  
  Depth: 112.0-113.0  
  Sample Number: CC-9

- Source of Sample: UL-565  
  Depth: 123.0-126.0  
  Sample Number: CC-10

---

**Client:** Sound Transit  
**Project:** University Link Project RTA/LR 8-06  
**Project No.:** J-07-2195  
**Figure:** 46
Atterberg Limits Test Report (ASTM D-4318)

Dashed line indicates the approximate upper limit boundary for natural soils

SOIL DATA

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>SOURCE</th>
<th>SAMPLE NO.</th>
<th>DEPTH</th>
<th>NATURAL WATER CONTENT (%)</th>
<th>PLASTIC LIMIT (%)</th>
<th>LIQUID LIMIT (%)</th>
<th>PLASTICITY INDEX (%)</th>
<th>USCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>●</td>
<td>UL-565</td>
<td>CC-12</td>
<td>150.0-152.0</td>
<td>23.8</td>
<td>22</td>
<td>44</td>
<td>22</td>
<td>CL</td>
</tr>
</tbody>
</table>

SOIL TECHNOLOGY

Bainbridge Island, WA

Client: Sound Transit
Project: University Link Project RTA/LR 8-06
Project No.: J-07-2195

Figure 53

Tested By: AJA
NB Boring Laboratory Results
PLASTICITY INDEX - PI (%) vs. LIQUID LIMIT - LL (%)

LEGEND

CL: Low plasticity inorganic clays; sandy and silty clays

CH: High plasticity inorganic clays

ML or OL: Inorganic and organic silts and clayey silts of low plasticity

MH or OH: Inorganic and organic silts and clayey silts of high plasticity

CL-ML: Silty clays and clayey silts

<table>
<thead>
<tr>
<th>BORING AND SAMPLE NO.</th>
<th>DEPTH (feet)</th>
<th>U.S.G.S. SYMBOL</th>
<th>SOIL CLASSIFICATION</th>
<th>LL %</th>
<th>PI %</th>
<th>PI %</th>
<th>NAT. W.C. %</th>
<th>PASS. #200 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB-389, S-18</td>
<td>81.1</td>
<td>CL</td>
<td>Gray-brown, silty CLAY, trace of fine gravel</td>
<td>44</td>
<td>25</td>
<td>19</td>
<td>28.7</td>
<td></td>
</tr>
<tr>
<td>NB-389, S-22</td>
<td>91.4</td>
<td>CH</td>
<td>Gray, silty CLAY</td>
<td>54</td>
<td>25</td>
<td>29</td>
<td>28.4</td>
<td></td>
</tr>
<tr>
<td>NB-389, S-32</td>
<td>116.9</td>
<td>ML</td>
<td>Gray, clayey SILT</td>
<td>40</td>
<td>27</td>
<td>13</td>
<td>28.2</td>
<td></td>
</tr>
</tbody>
</table>

Sound Transit
Sound Transit North Link
Seattle, Washington

PLASTICITY CHART
BORING NB-389
December 2004 21-1-08110-620
SHANNON & WILSON, INC. Geotechnical and Environmental Consultants FIG. D.2.2-60
# TABLE D.2.8-1

**SUMMARY OF UNCONFINED COMPRESSION TESTS ON SOIL**

<table>
<thead>
<tr>
<th>Boring No.</th>
<th>Sample No.</th>
<th>Top Depth (feet)</th>
<th>Unconfined Compressive Strength (tsf)</th>
<th>Strain at Failure (%)</th>
<th>Interpreted Geologic Unit</th>
<th>Soil Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB-387</td>
<td>S-28</td>
<td>90.5</td>
<td>1.5</td>
<td>4.0</td>
<td>Oqgl</td>
<td>Gray, silty CLAY</td>
</tr>
<tr>
<td>NB-389</td>
<td>S-18</td>
<td>81.1</td>
<td>5.7</td>
<td>2.8</td>
<td>Oqgl</td>
<td>Gray-brown, silty CLAY, trace of fine gravel</td>
</tr>
<tr>
<td>NB-389</td>
<td>S-22</td>
<td>91.4</td>
<td>1.7</td>
<td>1.2</td>
<td>Oqgl</td>
<td>Gray, silty CLAY</td>
</tr>
<tr>
<td>NB-389</td>
<td>S-32</td>
<td>116.9</td>
<td>0.5</td>
<td>0.8</td>
<td>Oqgl</td>
<td>Gray, clayey SILT</td>
</tr>
</tbody>
</table>

*tsf = tons per square foot*
**UNCONFINED COMPRESSION TEST NO. 1**

**SUMMARY OF TEST DATA**

- **Boring:** NB-389
- **Sample:** S-18
- **Depth, ft.:** 81.1

**CLASSIFICATION:**
Gray-brown, silty CLAY, trace of fine gravel (CL)

**SAMPLE DATA:**
- Spec. Grav. (est.): 2.70
- Liquid Limit: 44
- Plastic Limit: 25
- Plasticity Index: 19
- Specimen: UNDISTURBED

**SPECIMEN DATA:**
- Height, inches: 5.62
- Diameter, inches: 2.87
- Height/Dia. Ratio: 1.96
- Weight, grams: 1206.4
- Water Content, %: 23.4
- Wet Density,pcf: 126.2
- Dry Density,pcf: 102.3
- Saturation, %: 98

**TEST DATA:**
- Defl. Constant, in./div.: .001
- Load Constant, kg/div.: 1.982

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Div</td>
<td>Div</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0</td>
<td>9.5</td>
<td>2</td>
<td>6.48</td>
<td>41.5</td>
<td>.46</td>
<td></td>
</tr>
<tr>
<td>15.0</td>
<td>15.5</td>
<td>.3</td>
<td>6.49</td>
<td>67.7</td>
<td>.75</td>
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<tr>
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<td>6.49</td>
<td>100.5</td>
<td>1.11</td>
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<td>127.6</td>
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<td>152.9</td>
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<tr>
<td>40.0</td>
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<td>192.3</td>
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<td>6.54</td>
<td>260.0</td>
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<tr>
<td>75.0</td>
<td>71.0</td>
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<td>6.55</td>
<td>310.3</td>
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<tr>
<td>95.0</td>
<td>86.0</td>
<td>1.7</td>
<td>6.58</td>
<td>375.8</td>
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<tr>
<td>115.0</td>
<td>101.8</td>
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<td>6.60</td>
<td>444.9</td>
<td>4.85</td>
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</tr>
<tr>
<td>130.0</td>
<td>110.5</td>
<td>2.3</td>
<td>6.62</td>
<td>482.9</td>
<td>5.25</td>
<td></td>
</tr>
<tr>
<td>150.0</td>
<td>120.2</td>
<td>2.7</td>
<td>6.65</td>
<td>525.3</td>
<td>5.69</td>
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</tr>
<tr>
<td>157.0</td>
<td>121.2</td>
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<td>6.66</td>
<td>529.6</td>
<td>5.73</td>
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<tr>
<td>170.0</td>
<td>114.5</td>
<td>3.0</td>
<td>6.67</td>
<td>500.4</td>
<td>5.40</td>
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<tr>
<td>180.0</td>
<td>94.0</td>
<td>3.2</td>
<td>6.68</td>
<td>410.8</td>
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<tr>
<td>195.0</td>
<td>58.0</td>
<td>3.5</td>
<td>6.70</td>
<td>253.5</td>
<td>2.72</td>
<td></td>
</tr>
</tbody>
</table>

**FAILURE SKETCH:**

![Failure Sketch Image]

Puget Sound Transit Consultants
Sound Transit Link
Civil Facilities Design

**UNCONFINED COMPRESSION TEST**
**BORING NB-389, S-18**

**July 2002**

SHANNON & WILSON, INC.
GEOENGINEERING CONSULTANTS

Fig. D.21a

FIG. D.28-2a
UNCONFINED COMPRESSION TEST NO. 1
STRESS VS STRAIN

Boring: NB-389
Sample: S-18
Depth, ft: 81.1

Tested By / Date: RJT 5/13/02
Calc. By / Date: RJT 5/17/02
Check By / Date: KTB 5/18/02

Puget Sound Transit Consultants
Sound Transit Link
Civil Facilities Design

UNCONFINED COMPRESSION TEST
BORING NB-389, S-18
July 2002
21-1-08108-170

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

FIG. D-21b
FIG. D.2.8-2b
# UNCONFINED COMPRESSION TEST NO. 1

## SUMMARY OF TEST DATA

<table>
<thead>
<tr>
<th>Boring</th>
<th>NB-389</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>S-22</td>
</tr>
<tr>
<td>Depth, ft.</td>
<td>91.4</td>
</tr>
</tbody>
</table>

**CLASSIFICATION:**
Gray, silty CLAY (CH)

**SAMPLE DATA:**
- Spec. Grav. (est.) : 2.75
- Liquid Limit : 54
- Plastic Limit : 25
- Plasticity Index : 29
- Specimen : UNDISTURBED

**SPECIMEN DATA:**

<table>
<thead>
<tr>
<th>Before</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height, inches : 6.30</td>
<td></td>
</tr>
<tr>
<td>Diameter, inches : 2.81</td>
<td></td>
</tr>
<tr>
<td>Height/Dia. Ratio : 2.24</td>
<td></td>
</tr>
<tr>
<td>Weight, grams : 1277.3</td>
<td></td>
</tr>
<tr>
<td>Water Content, % : 27.8</td>
<td></td>
</tr>
<tr>
<td>Wet Density,pcf : 124.5</td>
<td></td>
</tr>
<tr>
<td>Dry Density,pcf : 97.4</td>
<td></td>
</tr>
<tr>
<td>Saturation, % : 100</td>
<td></td>
</tr>
</tbody>
</table>

**TEST DATA:**
- Defl. Constant, in./div. : .001
- Load Constant, kg/div. : 1.982

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>div</td>
<td>div</td>
<td>%</td>
<td>sq. in.</td>
<td>lb</td>
<td>tfs</td>
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<td>9.0</td>
<td>.2</td>
<td>6.21</td>
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<td>.46</td>
</tr>
<tr>
<td>20.0</td>
<td>13.0</td>
<td>.3</td>
<td>6.22</td>
<td>56.8</td>
<td>.66</td>
</tr>
<tr>
<td>30.0</td>
<td>16.8</td>
<td>.5</td>
<td>6.23</td>
<td>73.4</td>
<td>.85</td>
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<tr>
<td>40.0</td>
<td>20.5</td>
<td>.6</td>
<td>6.24</td>
<td>89.6</td>
<td>1.03</td>
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<tr>
<td>50.0</td>
<td>24.3</td>
<td>.8</td>
<td>6.25</td>
<td>106.2</td>
<td>1.22</td>
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<td>75.0</td>
<td>33.2</td>
<td>1.2</td>
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<td>145.7</td>
<td>1.69</td>
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<tr>
<td>88.5</td>
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<td>1.4</td>
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**FAILURE SKETCH:**

[Image of failure sketch]

Puget Sound Transit Consultants  
Sound Transit Link  
Civil Facilities Design  

**UNCONFINED COMPRESSION TEST**  
**BORING NB-389, S-22**  
July 2002  
21-1-08108-170  
SHANNON & WILSON, INC.  
GEOCENTERICAL AND ENVIRONMENTAL CONSULTANTS  
FIG. D-22a
UNCONFINED COMPRESSION TEST NO. 1
SUMMARY OF TEST DATA

Boring: NB-389
Sample: S-32
Depth, ft.: 116.9

Tested By / Date: RJT 5/13/02
Calc. By / Date: RJT 5/17/02
Check By / Date: RJT 5/24/02

CLASSIFICATION:
Gray, clayey SILT (ML)

SAMPLE DATA:
Spec. Grav. (est.): 2.78
Liquid Limit: 40
Plastic Limit: 27
Plasticity Index: 13
Specimen: UNDISTURBED

SPECIMEN DATA:
Before
Height, Inches: 6.17
Diameter, Inches: 2.82
Height/Dia. Ratio: 2.19
Weight, grams: 1227.8
Water Content, %: 32.7
Wet Density, pcf: 121.3
Dry Density, pcf: 91.4
Saturation, %: 101

TEST DATA:
Defl. Constant, in./div.: .001
Load Constant, kg./div.: 1.982

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FAILURE SKETCH:

Puget Sound Transit Consultants
Sound Transit Link
Civil Facilities Design

UNCONFINED COMPRESSION TEST
BORING NB-389, S-32
July 2002
SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS
FIG. D-23a

FIG. D.2.8-4a
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NOTES:

⁶⁺ Date sample removed from sampler and sealed in plastic bag.
⁶⁻ Time elapsed between date sample sealed in bag and date of gas measurement.
⁸ Field screening data collected by Shannon & Wilson.
⁹ Methane measurement is presented in units of parts per million.
CH₄ = methane, CO₂ = carbon dioxide, O₂ = oxygen, H₂S = hydrogen sulfide, ppm = parts per million
- Not measured or recorded.