

APPENDIX 6A

CSI Specifications for Cathodic Protection

INTRODUCTION

This appendix contains two standard specifications for cathodic protection. The specifications are presented in Construction Specifications Institute (CSI) MasterFormatLatest Edition:

1. Impressed Current Cathodic Protection System 26 42 00
2. Test Stations 26 42 01

SUMMARY SHEET

Section name: IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM

Section number: 26 42 00

Prepared by: Removed

Reviewed by: Removed for
Security

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WARNING: The standards and guidelines do not relieve licensed engineers from their responsibilities as outlined by the code of ethics and rules of practice. All specifications require editing and review by the project's licensed engineer and must be tailored to the conditions and needs of the project. The guidelines provide policy, clarity, and advice on how design should be conducted by and for Seattle Public Utilities. However, it remains the responsibility of the licensed engineer to properly interpret and apply the guidelines as appropriate to meet the needs of the project. If these standards and guidelines contain any contradictions with other standard engineering practices, the licensed engineer is responsible for identifying and resolving them.

This Section covers the work necessary to furnish and install impressed current cathodic protection systems for the various locations as identified for this project.

PART 1 GENERAL

1.1. RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 01 Specification Sections, apply to this Section.
- B. Section 26 42 01, TEST STATIONS.

1.2. SUMMARY

- A. Section includes: This Section covers the work and materials necessary to furnish and install impressed current cathodic protection systems for the various locations as identified for this project.

1.3. DEFINITIONS

- A. Lead, Lead Wires, Joint Bonds, Cable: Insulated copper conductor; the same as wire.
- B. Active Column: The anode and coke breeze portion of a deep anode ground bed that discharges electrical current.
- C. Inactive Column: The portion of a deep anode ground bed above the coke breeze that does not discharge electrical current.

1.4. SUBMITTALS

- A. Provide catalog cuts sheets and other information for all materials to be used and cross out information not used. Submittals must be made in accordance with Section 01 33 10 - Submittals.
- B. Cathodic Protection Specialist Credentials: The Contractor must submit the credentials of the Corrosion Specialist to the Engineer for review prior to starting the work. The submittal must include the following:
 - 1. Name of individual and current job title(s)
 - 3. Titles and dates of projects (minimum of 5 projects within the past 10 years).
 - 4. Employer with name and telephone number of contact person for each project listed.
 - 5. Contracting agency with name and telephone number of contact person for each project listed.
 - 6. Brief technical summary of work for each project listed, including pertinent details that are similar to this project.
- C. Drilling Experience Statement: Provide the following information:
 - 1. Name of the individual(s) who will operate the drilling equipment, current job title(s), and a copy of their current drilling license.
 - 2. Title of all projects (for experience) with dates for the past 5 years.
 - 3. Drilling company employer with name and telephone number of contact person for each project listed.
 - 4. Contracting agency with name and telephone number of contact person for each project listed.
 - 5. Brief technical summary of work for each project listed, including pertinent details that are similar to this project.
- D. Wire-to-anode connection resistance values per Section 26 42 00 2.3C, including test

instrument calibration certificate/records(s) and factory catalog cut sheet of wire-to-anode cable resistance values.

- E. Anode Installation Work Plan: A written description of the method to be used for lowering the cathodic protection anodes, vent pipe, anode centralizers, and installation of coke breeze into the holes. Work plan must include work sequence, ground bed resistance readings for pre and post anode installation, and on-site spot testing.
- F. A well log for full drilling depth to be submitted to the Engineer following anode installation. Core samples must not be taken. Well log must be based on cuttings and driller experience.
- G. Report of ground bed resistance measurement at every 10 ft interval before anode lowering work and resistance measurements of anodes after lowering.
- H. Impressed anode performance test report for all deep well anode systems.

1.5. QUALITY ASSURANCE

- A. General: The Contractor must provide a AMPP/NACE CP4 Certified Cathodic Protection Specialist with a minimum of 5 years of cathodic protection experience who will be on site during installation of the impressed current cathodic protection systems. The Cathodic Protection Specialist must be responsible to the Contractor to observe, inspect, and ensure the installations are in compliance with these specifications and testing services specified herein. The Cathodic Protection Specialist must have experience testing and monitoring the installation for at least five distributed anode system installations (for projects with distributed systems) and at least five deep anode cathodic protection installations (for projects with deep well systems), a minimum of 250 feet deep, and cathodic protection system components of comparable scope and complexity to those required under this contract. The Contractor must provide the services of the Cathodic Protection Specialist at the Contractor's sole expense.
- B. The Cathodic Protection Specialist must be present at the project site during the installation and backfill of the deep well and distributed cathodic protection anodes and must perform the deep well resistance tests specified during backfill operations and the anode performance test after installation. The Cathodic Protection Specialist must make additional visits to jobsites as required to determine compliance and to resolve field problems should any problems occur and shall notify SPU in writing if there is any interruption in coke breeze backfill and/or wire insulation damage. Any damage to anodes or cut, gouged, or scraped wire insulation will not be acceptable.
- C. Driller's Experience: Driller must have installed a minimum of three deep wells, a minimum of 300 ft deep and 8-in diameter, within the last 5 years. Drillers must be licensed in accordance with WAC 173-162.

PART 2 PRODUCTS

2.1. GENERAL

- A. The use of a manufacturer's name and model or catalog number is for the purpose of establishing the standard of quality and general configuration desired only. Products of other manufacturer's will be considered in accordance with the General Conditions.

2.2. MATERIAL SUPPLIERS

- A. Suppliers listed below can usually supply the types of materials specified in this Section. Alternate suppliers will be considered, subject to approval of the ENGINEER. Address given is that of the general office; contact these offices for information regarding the location of their representative nearest the project site.
 - 1. Farwest Corrosion Control, Gardena, CA.

2. Mesa Products, Inc., Tulsa, OK.
3. Norton Corrosion Limited, Woodinville, WA.
4. Corpro – Aegion, Inc. Houston, TX

2.3. IMPRESSED CURRENT ANODES

- A. Cast Iron Type: Tubular, center-tap connection, high-silicon chromium cast iron centrifugally cast for high density, with the following dimensions and chemical composition, or as specified in the drawings:
 1. Dimensions:
 - a) Length: 84 inches minimum.
 - b) Outside Diameter: 2-21/32 inch minimum.
 - c) Wall Thickness: 13/32 inch minimum.
 - d) Weight: 69 pounds minimum.
 2. Composition:
 - a) Silicon: 14.20 to 14.75 percent.
 - b) Manganese: 1.50 percent maximum.
 - c) Carbon: 0.70 to 1.10 percent.
 - d) Chromium: 3.25 to 5.00 percent.
 - e) Copper: 0.50 percent maximum.
 - f) Molybdenum: 0.20 percent maximum.
 - g) Iron: Remainder.
3. Acceptable Anodes: Anotec "Centertec" Type 2684 Z, manufactured by Anotec, Industries Ltd., or approved equal.
 - a)
- B. Anode Tests at the Fabrication Facility: The anode supplier must conduct and submit to the Engineer the result of factory resistance tests for each anode lead wire connection to assure the finished connection falls within +/- 10 percent of the specified resistance value. Results must be submitted to the Engineer a minimum 10 working days prior to anode installation. All wire-to-anode connections that exceed the specified resistance value must be replaced by the anode supplier. Wire-to-anode resistance records must include the following:
 1. Anode numbering system to identify the anode tested.
 2. Anode lead length (varies per site).
 3. Each anode lead length resistance, measured, before connection to anode.
 4. Resistance value of anode-to-wire connection as indicated by the test.
 5. Test equipment used with calibration certificated dated within 2 years max.
 6. Test methods.
 - 7.
- C. Anode Test on-site prior to installation: The Contractor must set up equipment and demonstrate the anode resistance test to the SPU CP specialist who will select three to four anodes for verification of resistance measurements. The anodes must be available for selection at least 2 working days before the anodes are installed. Failure of this anode to pass the resistance test or tensile test on the wire-to-anode connection will cause to reject the

entire anode shipment.

- D. Anode Wire: Supply each anode per Section 26 42 00 2.20 of sufficient length to extend splice-free from the anode connection to the anode terminal junction box plus 1 foot slack. Deep well anode wires must be spooled on wooden reels and arranged on-site for installation such that the wires unspool smoothly without tangling and causing undue tension.
- E. Cable Guides: Provide all anodes with a cable guide where the anode wire enters the anode tube to prevent damage to the wire insulation during handling and installation.
- F. Wire-to-Anode Connection: Each anode must have a center-connect lead wire. The maximum electrical resistance of the connection must not exceed 0.004 ohms. The maximum pull out strength of the anode lead wire must exceed that of the breaking box plus 3 feet.
- G. Anode Caps: The anode cap material must be water resistant and form a tightly bonded seal to the anode material and lead wire.
- H. Wire Labels: For Deep Anode Ground Bed installations, label the end of each anode wire with the anode number and total wire length, stamped onto brass tags. The anodes must be numbered sequentially from the bottom to the top. Bottom anode must be labeled No. 1.

2.4. ANODE CENTRALIZERS

- A. Anode centralizers must be metallic material and capable of centering the anode in the well without blocking the hole or impairing installation of other anodes, anode lead wiring, or coke breeze.
 - 1. Centralizers must have a minimum diameter equal to 80% of the well diameter.
 - 2. Acceptable anode centralizers: Mesa model Cen-52 Centralizer, manufactured by Mesa Products; LIDA Ventralizer, manufactured by De Nora Industries, or approved equal.

2.5. COKE BREEZE (FOR DEEP ANODE GROUND BEDS)

- A. Type: Lubricated, low resistance, calcined petroleum coke, suitable for pumping, with the following composition:
 - 1. Volatile Matter: 0.25 percent maximum.
 - 2. Ash: 0.5 percent maximum.
 - 3. Sulfur: 1.6 percent maximum.
 - 4. Fixed Carbon: 99 percent minimum.
 - 5. Particle Size: 100 percent passing 16 mesh and 98 percent retained by 200 mesh.
 - 6. Bulk Density: 74 pounds per cubic foot minimum.
 - 7. Maximum Resistivity: 0.10 ohm-cm at 150 psi.
- B. Acceptable Coke Breeze: Loresco Type SC3, or approved equal.

2.6. SURFACE VENT PIPE

- A. Schedule 80 PVC, 1 1/4-inch diameter or as noted on drawings.
- B. Couplings and fittings for the vent pipes must be Schedule 80, high-impact, rigid PVC. Fasten vent couplings and fittings with solvent-welded joints or Engineer-approved alternate in accordance with the manufacturer's written instructions.
- C. The top of the vent pipe must be fitted with a watertight removable cap.

2.7. DOWNHOLE VENT PIPE

- A. Downhole vent must be constructed of perforated Schedule 80 PVC for the entire length of active column, 1 1/4-inch diameter pipe or as shown on the drawings.
 - 1. Acceptable vent pipe: Loresco All-Vent, manufactured by Loresco International, Hattiesburg, MS, or approved equal.
- B. Couplings and fittings for the vent pipes must be Schedule 80, high-impact, rigid PVC. Fasten vent couplings and fittings with solvent-welded joints or ENGINEER-approved alternate in accordance with the manufacturer’s written instructions.
- C. The bottom of the vent pipe must be sealed with a plastic end cap or plug.

2.8. CASING

- A. Well casing for the active column, if used, must be standard weight perforated steel in new condition. Steel casing must not be left in place above the active column. Starter (surface) casing must be PVC and installed as indicated on the drawings. Plastic starter casing must meet or exceed ASTM Standard F-480. All plastic casing must be in good condition, durable, and watertight. Plastic casing material must be nontoxic and resistant to water and soil corrosiveness. Casing must meet local well drilling standards and state and local codes for well drilling and be able to withstand installation, grouting, and operational stresses. Plastic casing must not be used in the active column of the ground bed.

2.9. GROUND BED SEALING MATERIALS

- A. Ground bed sealing materials must be in accordance with state and local regulations.
- B. Cement Grout: Composed of two parts by weight sand to one part cement and 5 to 7 gallons of water per sack of cement. Gradation of the sand must fall within the following limits:

Sieve	Percentage Passing
3/8-in.	100
No. 4	95 to 100
No. 16	45 to 80
No. 50	10 to 30
No. 100	2 to 10

- C. Bentonite Grout: Specifically designed for the purpose of constructing or decommissioning wells, such as Loresco Perma Plug available from Loresco International, Hattiesburg, MS, or approved equal.
- D. Puddling Clay: Stable, fine-grained (0.5 mm to 1 mm), impervious material and at least 50 percent bentonite, by volume, which is capable of providing a permanent water tight seal throughout the required sealing depth.

2.10. DEEP ANODE WELL CAP

2.11. Two-piece, cast iron well seal with a rubber packer to form a watertight seal. Seals must allow vent pipe and anode cable penetrations with rubber packing providing a watertight seal of the annular space. Acceptable seals are available from Campbell Manufacturing, Bechtelsville PA; Berkeley Pump Company, Berkeley CA; or approved equal.
ANODE TERMINAL JUNCTION BOX

- A. Terminal Junction Box: Installed inside rectifier cabinet.
- B. Panels: Panels for mounting terminal studs must be 1/4 inch thick phenolic.

- C. Terminals and Connectors: Provide copper bus bar(s), terminal studs, connectors, and all necessary fasteners to connect the anode and rectifier wires.
 - 1. Copper Bus Bars: 1/4-inch and 3/4-inch, length as required.
 - 2. Terminal Studs, Washers, and Nuts: 1/4-20 nickel-plated brass.
 - 3. Connectors: Offset pressure tongue with hex head, solderless lugs, sized for the wire to be connected. Burndy series KPA, Panduit series CB, Blackburn copper mechanical lugs, or approved equal.
- D. Shunts: Agra Type JB, 0.01 ohm with 5 ampere capacity and holes for 1/4- inch diameter fasteners.
- E. Identifications: Supply plastic self-laminating cable lables or equal for all electrical wire. Anode supplied cable idetification must be placed within two to three inches of anode terminal studs.

2.12. RECTIFIER

- A. Rectifier Manufacturers: The rectifiers must be UL listed or NRTL/ETL certified and the product of a company currently engaged in the manufacture of cathodic protection equipment and must conform in all respects to NEMA and NEC Standards.
- B. General: Air cooled, manually controlled meeting NEMA standards. The rectifier must be designed to operate continuously at an ambient temperature of 45 degrees C and must be capable of 110 percent of rated input without damage to the rectifier components.
- C. AC Input as required or shown on the drawings
 - 1. 115/230 volts, single-phase, 60 Hz. Provide main two pole thermal magnetic circuit breaker sized per required output rating, mounted on the rectifier front panel.
 - 2. 480 volts, three-phase, 60 Hz. Provide a suitably sized thermal magnetic circuit breaker mounted on the rectifier front panel.
- D. Transformer: Two-winding, insulating type, meeting the requirements of NEMA, UL, and CSA. Provide with fine and coarse secondary taps with rectifier output controlled by a minimum of 20 evenly divided steps of adjustment. Coarse and fine taps must be arranged in consecutive order. All transformer insulation must be rated for a minimum temperature of 130 degrees C with actual hottest spot temperature at rated conditions not to exceed 100 degrees C.
- E. Rectifying Elements: Full wave bridge, silicon diode stack with efficiency filter choke, with metal oxide thyristors and current limiting devices for overvoltage and overcurrent control and protection of the stack.
- F. Output rating: 50 volts, 30 amperes or as indicated on the drawings.
- G. Lightning Protection: Provide lightning protection devices for AC input and DC output. AC lightning protection must be rated to absorb up to 1,000 joules of energy per phase. The DC protection must be rated to absorb 500 joules. Furnish one spare set of lightning protectors for each rectifier.
- H. Meters: Separate DC voltage and current meters, D'Arsenval jeweled movement type, accurate to within 2 percent of actual voltage and current output. Meters shall be field tested for accuracy; inaccurate meters shall be replaced.
- I. Shunt: Holloway type shunt mounted in series with the ammeter, with voltage and current clearly identified on shunt body. Shunt must be 50MV to 50A, or similar, to provide 1:1 reading ratio.

- J. NEMA 3R Enclosure: 14-gauge stainless steel 36" width x 24" deep x 42" high. Provide with hinged doors on both sides to allow access, stainless steel latches, and hasp for locking. Enclosure must be sealed to protect the interior components from weather, vandalism, and nest building insects, and must provide adequate ventilation. Install per City of Seattle Std., Plan 500 and drawings.
- K. Panelboard: Non-metallic, suitable for mounting meters, shunt, circuit breaker, fuses and output terminals. Panelboard must be located as shown on drawings and to allow access for testing and adjustment. Clearly engrave or identify with a permanent marking system the polarity of output terminals, fine and course transformer tap settings, meters, and fuses. All anode terminations must occur on this panel board opposite side from the rectifier location, as shown on drawings.
- L. Convenience Outlet: Provide a 115V AC 15A rated Ground Fault Interrupting (GFI) convenience outlet installed on the rectifier panel.
- M. Current Interrupter: Provide a solid state timing device to interrupt secondary current. Interrupter must be capable of continuous operation, and must consist of a 1-minute adjustable recycling mechanical timer or electronic timer, a "Test-Normal" toggle switch, and a relay or connector to interrupt the main current.
- N. Mounting Hardware: Tap studs, tap bars, nuts, washers and other mounting hardware must be suitably sized brass or tin-plated copper.
- O. Nameplate: Engraved metal plate mounted on the interior side of the front door listing the manufacturer name, model number, serial number, year manufactured, and AC and DC input and output electrical ratings.
- P. Rectifier Enclosure Nameplate:
1. Attach a permanent nameplate to the exterior of each rectifier enclosure. Locate the nameplate 1 ft below the top and centered on the door providing access to the front of the rectifier. Nameplate must be engraved into a 2-inch by 8-inch 18-gauge stainless steel plate. Lettering must be 0.375 inch high and filled with blue paint. Provide the following words on the nameplate, in two lines:

SEATTLE PUBLIC UTILITIES
CATHODIC PROTECTION
 2. The completed nameplate must be coated with a clear polyurethane enamel with exterior catalyst and attached to the rectifier enclosure door with a minimum of four aluminum rivets.
- Q. Operation and Maintenance Manuals: Provide two copies of operation and maintenance manuals that include electrical schematics of the rectifier, parts list with part replacement number, and troubleshooting procedures.
- R. Acceptable Rectifiers:
1. Universal Rectifiers, Farwest DCPro Cathodic Protection Power Supply, or approved equal.

2.13. POWER SERVICE

- A. Service risers, conduits, and termination handholes from power poles to meter sockets at rectifier cabinets must meet contract drawings and SCL Construction Standards and Guidelines U7-10/NDK-70, U7-10.1/NDK-80, U2-13.1/NVH-50, U2-10/NDK-50. See SCL customer approved drawings in Section 00 31 10 for SCL requirements.
- S. PVC service entrance weatherhead and SCH-80 PVC conduit including bracket support arms/stand-off brackets must be furnished and installed for every service. SCL shall mount the top portion of the PVC conduit and weatherhead .

2.14. MARKING TAPE

- A. Marking tape for buried cathodic protection system underground conductors must be red, 3 inches wide with the words "Caution Electric Lines Buried Below," and be buried at 12 inches below finish grade or 12 inches minimum above conductors/conduits or as noted on plan.

2.15. GROUND ROD AND WELL

- A. Copper-clad steel, 3/4-inch diameter by 10 ft long. The ground rod well must be installed as shown on the plans 10' away from the ground rod inside the rectifier cabinet.

2.16. GROUND WIRE AND CLAMP

- A. No. 4 AWG continuous from service equipment to two ground rods via PVC sleeve through the cabinet's concrete pad per detail. The ground wire shall be bare stranded copper wire with a high copper content alloy or bronze bolt-on ground rod clamp or Cadweld Type GR or GT, or equal. "One Shot" Cadweld will not be allowed.

2.17. CONDUIT, LOCKNUTS, AND STRAPS

- A. Fittings and Rigid galvanized steel, PVC Schedule 80 conduit, or as indicated on the plans must be UL listed for direct burial. Conduit and fittings must meet the requirements of NEMA TC and TC3, Federal Specification W-C-1094, UL, and NEC.
- B. Locknuts, Two-Hole Straps, and Miscellaneous Hardware: Hot-dipped galvanized steel.
- C. Conduit Bushings: Rigid galvanized steel fitting and bonding per current NEC and drawings as shown.

2.18. CONCRETE

- A. Reinforcing Steel: ASTM A615, Grade 60 deformed bars.
- B. Welded Wire Fabric: ASTM A497.
- C. Formwork: Plywood.
- D. Mix: ASTM C94, Option A.
 - 1. Cement: ASTM C150, Type II, with maximum alkyl content of 0.606 percent.
 - 2. Coarse Aggregate Size: 3/4 inch.
 - 3. Design for Minimum Compressive Strength at 28 Days: 2,500 psi.

2.19. BOLLARDS

- A. Per COS standard plan NO. 463 or as noted on drawings.

2.20. ELECTRICAL WIRE

- A. Rectifier to Pipelines: Conductors must be UL listed No. 2 AWG stranded copper with 600-volt rated, high molecular weight polyethylene (HMWPE) insulation or as noted on drawings. HMWPE insulation must be a minimum of 7/64-inch thick.
- B. Impressed Current Anode Leads: Single-conductor, No. 8 AWG stranded copper with a 20-mil thick Halar primary insulation and a 65-mil HMWPE outer jacket. Acceptable anode wire is Rome Halar/HMW Polyethylene Cathodic Protection Cable, as manufactured by Rome Cable, or approved equal.
- C. Distributed Anode Header Cables must be No. 2 AWG stranded copper with 600 volt rated, HMWPE insulation or as indicated on the drawings.

1. Where two anode header cables run in parallel, in a separate or same trench, terminate the two ends of header cables with 1 ft each coiled wire inside a COS Type 1 handhole within 2 ft of the adjacent test station or as indicated on the plan. Wires must be 12 inches below grade and covered with a minimum of 6 inches of sand inside the handhole.
- D. D. AC Conductors: All wire must be UL listed sized per plan. Service entrance conductors from power pole/transformer to utility termination handholes or meter sockets must be per SCL/PSE requirements as shown in SCL/PSE customer drawings in Section 00 31 10. Service conductors from the handhole to utility meter base, if not shown in SCL/PSE customer drawings must be sized per NEC or as indicated on the Drawings.

2.21. THERMITE WELD MATERIALS

Reference Section 9-30.8 – Thermite Weld Materials.

2.22. PIPE AND FITTING COATING REPAIR MATERIAL

Reference Section 9-30.8(4) – Coating Repair at Thermite Weld.

2.23. WIRE CONNECTORS

- A. One-piece, tin-plated crimp-on lug connector as manufactured by Burndy Co., Thomas and Betts, or approved equal.
- B. Anode Splice Encapsulation Kit:
 1. "C"-Taps COPPER PRESS-ONS Type CCT for connection of distributed anode lead wire to header cable
 2. Epoxy splice kit or anode splice encapsulation kit using heat shrinkable sleeve internally coated with self-encapsulating adhesive insulations, as manufactured by 3M or approved equal.
- C. Header Cable Splice:
 1. Heat-shrinkable wrap-sleeve with insulation stop or black insulation tape for inline header cable connection.

PART 3 EXECUTION

3.1. GENERAL

- A. The installation of the facilities herein specified and described must conform to the latest applicable rules and as set forth herein.

3.2. DEEP ANODE GROUND BED INSTALLATION

- A. General:
 1. All drilling operations and reporting requirements must conform to, as a minimum, the Washington Water Well Construction Standards WAC 173-160 and WAC 173-162.
 2. Drilling, lowering of anodes, coke breeze placement, and backfilling must be done in one continuous operation, and must be observed by the Contractor's Cathodic Protection Specialist and by the SPU Cathodic Protection Specialist.
 3. Drilling and waste disposal must be done in accordance with the methods and procedures of the best recognized practices and must comply with the rules and regulations of the State and County, or other governing bodies having jurisdiction. Hole must be sealed as specified herein or as required by local well drilling regulations. The most stringent regulations must apply.

4. The Contractor must take all necessary precautions to avoid entrance of foreign matter into the hole, movement of soil strata, or collapsing of the hole during the progress of the work. Should movement of soil strata or collapse of the drilled hole interfere with proper completion of the ground bed, the Contractor must recover the wires and anode strings, and ream or redrill the hole, at the Contractor's sole expense. Anodes must be replaced if necessary.
5. At all times during progress of the work, the Contractor must protect the well in such a manner as to effectively prevent tampering or entrance of foreign matter.

B. Drilling:

1. Coordinate and verify the actual location of the ground bed hole in the field with the Engineer before drilling begins. SPU will provide locate marks for pipeline(s), but Contractor must drill/excavate the first 10 ft of the hole using a vactor excavation method to ensure ground bed hole is clear of underground utilities.
2. The hole must be constructed, casing set round, straight, and plumb.
3. Surface casing must be set prior to completion of the first 50 ft of the hole. Casing, other than the surface casing, must not be installed or left in the hole unless in the driller's estimation it is necessary for successful completion of the hole.
4. If steel casing is installed in the active column, it must be cut at the top of the active column (bottom of the inactive column) of the well. Cutting and jacking operations may be completed before or after installation of the anode assembly at the Contractor's option and expense. Plastic casing installed in the inactive column must not exceed depth indicated on the plan not extend into the well active column. The hole must be over drilled as required to compensate for sloughing or heaving during anode installation.

C. Lowering of Anodes:

1. Prior to lowering anodes, the Contractor must submit an installation plan for approval by SPU describing the following:
 - a) Method of lowering anodes to avoid stress on lead wire.
 - b) Method of installation of coke breeze and centering of anode during installation in the drilled hole.
 - c) Include material submittals for any materials proposed for this work that we have not already been submitted.
2. Each anode wire will be inspected along its entire length by the Engineer prior to placement in the anode well. The terminal end of anode wires must be identified with weather-proof 3M marking tape, or by other approved method, before lowering the anodes into the hole.
3. Lowering of the anodes must be done after the drilling is completed. Actual lowering of the anodes and backfilling with coke breeze must be observed by the Engineer and SPU Cathodic Specialist.
4. Installation of the anodes and coke breeze must be performed on the same day as the completion of the drilling and electrical logging
5. Attach anode centralizers to each of the anodes prior to lowering.
 - a) Do not lift or support anode by the anode lead wire
 - b) If steel casing is used in the active column, the anode centralizers must be electrically isolated from the casing as such non-metallic centralized devices or by a method approved by the Engineer.
 - c) Anode centralizers must have no sharp edges that can damage wire insulation. Tape or

otherwise cover sharp edges of centralizers, as approved by the Engineer.

6. Install anodes and vent pipe in the drilled hole using methods previously approved by the Engineer. Deep anode cathodic protection components must not be installed prior to approval of the installation method by the Engineer.
 7. Vent pipe couplings must be attached to the vent pipe using a method approved by the Engineer. The Contractor must maintain the structural integrity of the vent pipe when lowering the deep well anodes.
 8. Any damage to anodes or cut, gouged, or scraped wire insulation will not be acceptable. No splices to anode wires will be allowed.
 9. If the hole is drilled with mud, it must be flushed with clean water in a continuous process before or after the anodes are lowered, at the Contractor's option, until the return fluid is sufficiently clear to allow proper installation and settlement of the coke breeze. The Engineer must inspect the return fluid before the coke breeze installation will be permitted to begin.
- D. Backfilling of Anode Hole:
1. The hole must remain full of water during installation of the coke breeze.
 2. Prepare a coke breeze slurry with water in accordance with the manufacturer's written recommendations. The coke breeze slurry must be pumped into the hole at high pressure through an additional pipe supplied by the Contractor. Pump the coke breeze in an even and continuous manner from the bottom of the hole to the top of the active column. Contractor must collect water that is displaced from the ground bed hole during coke breeze installation. Dispose of water in accordance with local, state, and federal regulations.
 3. The Contractor's Cathodic Protection Specialist must conduct resistance measurements between an appropriate grounded structure or the pipeline and each anode lead before and while pumping coke breeze. The individual anode resistance measurements must start at the bottom anode. The resistance value must decrease on each anode as the coke breeze is covering the anode. When the resistance measurement indicates that the coke breeze level has covered the bottom anode, the test leads must be connected to the next higher anode wire and the resistance measurement monitored as the coke breeze is installed. The resistance measurements must be used by the Contractor to monitor the coke breeze level in the drilled hole and detect possible coke breeze voids and/or bridging problems during installation.
 4. If voids, or bridging occurs during introduction of the coke breeze, the operation must cease until the voids have been eliminated. The Contractor must correct the deficiency, such as injecting potable water into the hole via the vent pipe, to the satisfaction of the ENGINEER.
 5. The Contractor must allow the coke breeze to settle for 12 hours before installation of the permanent well seal. After 12 hours, the depth of the coke breeze must be measured and additional coke breeze added to achieve the required plan elevation.
- E. Placement of Seal:
1. Place seal by pumping or forcing material as specified from top of grouted plug to within 4 ft of finished grade. Place seal in such a manner that ensures entire filling of the space in one continuous operation.
 2. Install sealing material in the annular space between the casing and the soil.
- F. All anode wires must pass through the well seal cap with a rubber bushing.
- G. Ground Bed and Vent Pipe Termination: Place vent pipe through well cap/seal, or PVC casing, and connect the steel portion of the vent pipe to the plastic vent pipe with the

appropriate threaded coupling, 24 inches minimum below grade. Place well cap in casing and torque bolts in accordance with the manufacturer's recommendations.

- H. Secure the vent pipe to a unistrut support located at the rectifier.

3.3. DISTRIBUTED ANODE GROUND BED INSTALLATION

A. General

- 1. The installation of the facilities herein specified and described must conform to the latest applicable rules and as set forth herein.

B. Drilling

- 1. Coordinate and verify the locations of each anode hole in the field with the Engineer before drilling begins. SPU will provide locate marks for pipeline(s), but the Contractor must drill/excavate the first 10 ft of the hole using a vactor excavation method to ensure the ground bed hole is clear of underground utilities .

C. Anode to header cable connection

- 1. Connection of new anodes to existing or new header cable must be made by removing the header cable insulation for a length necessary to make the electrical connection without damaging existing wire strands. Do not cut and splice header cable when making anode cable connection. Connect NO. 8 AWG STR (or size as shown on plans) anode cable to header cable with hydraulic crimped copper press-ons "C"-Tap connectors sized per header cable.
- 2. Connection must be made by encapsulating with an epoxy splice kit or anode splice encapsulation kit using heat-shrinkable sleeve internally coated with self-encapsulating adhesive insulation or equal. The remaining cable insulation that will be covered by the epoxy splice kit must be roughened with 100 grit sandpaper to provide additional surface area and roughness for bonding to the epoxy.

D. Lowering of distributed anodes:

- 1. Prior to lowering the anodes, the Contractor must submit an installation plan for approval by SPU describing the following:
 - a) Method of lowering anodes to avoid stress on lead wire.
 - b) Method of installation and anode centering in the hole, and amount of coke breeze for each hole..
 - c) Include material submittals for any materials proposed for this work that have not already been submitted.
- 2. Pour at least 10 gallons of water per anode hole after backfilling coke breeze material and before backfilling with native/import material.
- 3. Every anode lowered requires the presence of SPU cathodic protection staff. If SPU staff is not present, the installation will not be accepted.

3.4. RECTIFIER GROUNDING CONDUCTOR

- A. Rectifier grounding electrode conductor must be buried at 24 inches below grade and bonded to cabinet foundation rebar exposed inside cabinet as well as connect to the ground rod inside the cabinet and service disconnect.
- B. Equipment grounding conductor must be installed to the rectifier enclosure using the grounding lug provided by the rectifier manufacturer.

3.5. TRENCHING AND BACKFILL

- A. Complete excavations and trenching regardless of the type, nature, or condition of materials encountered, as required to accomplish specified construction.
- B. Take care to avoid damage to existing structures and utilities during excavating and trenching process. Cathodic protection excavations and cable trenches must be in the general location and route as shown. Contractor may modify location as approved by the Engineer as required to minimize possible damage to existing structures. Trench must be of uniform depth and width, level, smooth, and free of sharp objects. Hand trenching may be required in some areas to avoid damage to existing structures, landscaping, or tree roots.
- C. Sheet and brace excavations and trenches as necessary to prevent caving during excavation in unstable material, or to protect adjacent structures, property, workers, and the public.
- D. Backfill trench above the pipe zone with excavated backfill materials, tamp, and compact so that no subsequent settlement will occur. Do not use backfill material of frozen or consolidated debris. Leave the trench with the excess backfill material neatly mounded not more than 4 inches above the existing ground level for the entire width of the trench only in unimproved SPU right-of-way.

3.6. SLAB AND BOLLARD ASSEMBLY

- A. Fabricate assemblies, setting posts plumb and straight with concrete footing. Fill posts with concrete and top with rounded grout plug or as noted on Drawings.
- B. Grind all rough spots or sharp edges or steel posts. Solvent clean (SSPC SP-1) and coat with 1 coat of rust inhibitive primer and two coats of yellow alkyd enamel paint. Total coating system must be 6 mils dry film thickness, minimum.

3.7. CONDUITS

- A. Unless otherwise noted on the Drawings, all conduits must be rigid galvanized steel.
- B. Conduit must be sized per the number of conductors in accordance with the NEC or as indicated on the Drawings.
- C. Conduits entering cabinets, junction boxes, or terminal boxes must be secured with conduit hubs.
- D. Conduit separation must comply with SCL standards for SCL service conduit. Maintain minimum of 2 inches of conduit separation for SPU conduits.
- E. Use watertight couplings and connections. Install junction boxes and fittings to prevent water from entering the conduit or electrical panel. Seal all unused openings.

3.8. ANODE TERMINAL PANEL INSTALLATION

- A. Connect the rectifier positive lead and anode junction panel with #2 AWG wire and mechanical lugs rated not less than or match the ampacity of conductors.
- B. Label wires in the terminal box with heat-shrink tags or self-laminating cable labels. Anode wire identification must be the anode supplied tags associated with the anode number and associated depth. Connect numbered anodes in consecutive order to anode terminals starting with number 1 at the top left-hand side. Maintain sufficient slack (12-inch minimum) to keep the wire from being unduly stressed, damaged, or broken during backfill.

3.9. RECTIFIER INSTALLATION

- A. Contractor must verify rectifier enclosure dimensions and align anchor bolts locations and align conduit stub-ups with interior devices prior to forming rectifier concrete foundation.

- B. Provide conduits, fittings, conductors, and electrical hardware necessary to complete rectifier installation.
 - 1. Install raceway system for all power circuits within rectifier cabinet.
- C. Terminate #2 AWG wire connected to pipelines to rectifier negative terminal. Connect deep well anode cable to rectifier positive terminal. All wiring must have identification labels, white heat shrinkable tubing with black letters.
 - a. Provide double lugs for sites with more than one protected pipeline.
- D. Provide the Engineer with 10 working days prior notice to the completion of the rectifier, ground bed, and AC power service installation to allow scheduling of the required energizing and testing.

3.10. AC POWER SERVICE

- A. The Contractor must coordinate with SCL/PSE for service meter base, conduits, riser(s) installation inspection at least two weeks prior to scheduled construction. Notify the Engineer of the schedule with minimum one week advance notice prior to inspection taking place. SPU will pay for SCL/PSE for utility connection fees and inspection services that are required.
- B. The Contractor must be responsible for scheduling SCL/PSE service connection for every service location within the first 30 days of the construction..
- C. Contractor must mount meter base on rectifier enclosure and connect service disconnect per SCL/PSE requirements and current NEC.
- D. Service entrance disconnect must be bonded to the system ground rods and grounding and bushing to cabinet and conduits per current NEC.
- E. Drive ground rods straight down per current NEC and do not bend ground rods. Bond No. 4 AWG bare copper ground wire to the two ground rods and exposed rebar inside service cabinet.
- F. Install permanent label with utilities available fault current and date on service disconnect equipment and meter bases.

3.11. CONDUCTOR INSTALLATION

- A. Conductors buried at 30" minimum in the ground must be laid without kinks. The bottom of the finished trench must be free from stones, roots, or other materials which might damage conductor insulation or conduit. All cables from top of pipe or anode hole to enclosures must be installed in conduit.
- B. Power conductors must be continuous, no underground splices, and installed in a raceway system buried at 30 inches depth in right-of-way and 36 inches depth where across active streets.
- C. No wire bend must have a radius of less than 8 times the diameter of the wire. Copper or bronze offset pressure tongue with hex head solderless lugs must be used to make all cable connections to terminal studs.
- D. Provide Minimum of 2 ft length of wire slack where terminated in test stations or handholes.
- E. Conduits are installed with ¼" pull strings and no wire must be drawn into conduit until conduit system is complete. Lubricant must be approved by wire manufacturer.
- F. Arrange conductors neatly in rectifier and junction or terminal box. Cut to proper length, remove surplus wire, and attach terminal or connect to appropriate junction box or rectifier terminals.
- G. Seal all below ground conduit to prevent intrusion of foreign material after wire is in place.

- H. Bury warning tape approximately 12 inches above all underground rectifier conductors and conduits or as noted on the plan. Align parallel to and within two inches of the centerline of the conduit or conductor run.

3.12. WIRE CONNECTIONS

- A. The electrical connection of copper wire to steel, ductile and cast iron surfaces must be by the thermite weld method. Observe proper safety precautions, welding procedures, thermite weld material selection, and surface preparation as recommended by the welder manufacturer. Assure that the pipe or fitting wall thickness is of sufficient thickness that the thermite weld process will not damage the integrity of the pipe or fitting wall or protective lining.
- B. Before the connection is made, the surface must be cleaned to bare metal by making a 2-inch by 2-inch window in the coating, and then filing or grinding the surface to produce a bright metal finish. Use grinding wheels that do not leave residual material on metal surface that could affect thermite weld, as approved by the thermite weld manufacturer. The prepared metal surface must be dry.
- C. Wire sleeves must be installed on the ends of the wires before welding to the metal surface. Thermite welding must be performed in strict accordance with the manufacturer's written instructions. After the weld connection has cooled, remove slag and physically test wire connection by tapping with a hammer; ; remove and replace any defective connections.
- D. For thermite weld connections to concrete cylinder pipe, clean surfaces in accordance with SSPC SP1 and apply epoxy repair coating. After the epoxy coating has dried sufficiently, cover the connection with 3/4 inch to 1 inch of cement mortar. Repair coatings must be placed over all exposed steel where cement mortar was removed. For thermite weld connections to manholes or other pipe surfaces not coated with cement, extend the repair coatings a minimum of 2 inches from all edges of the completed thermite weld. As an alternative to the methods described above for sealing of thermite welds, see Section 16641, 2.08 THERMITE WELD CAPS and 2.09 PIPE AND FITTING COATING REPAIR MATERIAL.

3.13. ENERGIZING AND TESTING

- A. Electrical power circuits must be verified prior to energizing with ACE power.
 - 1. At a minimum, these tests must consist of the following by a licensed electrician:
 - a) Test for electrical continuity of each circuit.
 - b) Test for grounds in each circuit. This will consist of physical examination of the installation to ensure that all equipment grounding conductors are properly installed to electrical devices and all metallic enclosures are mechanically firm, meeting the requirements NEC articles 250.
 - 2. Apply AC power to service disconnects but do not turn on rectifier.
- B. Contact SPU CP specialist to field verify installation, power to rectifier unit, and set the required output for anode performance testing. The Contractor's cathodic protection specialist must perform tests to ensure proper impressed anode installation and operation of the completed cathodic protection system.
- C. Reports:
 - 1. After completion of all tests and inspections, the cathodic protection specialist will provide a detailed report of deficiencies to the Contractor. Provide a system performance report of project requirements, including recommendations and corrective actions taken for the effective CP operation. The Contractor must make all repairs necessary to correct these deficiencies at the Contractor's sole expense.

2. The Contractor's cathodic protection specialist will retest items that have been repaired by the Contractor. All testing, deficiencies, and corrections must be summarized in a report and submitted to the Owner.
- D. After the Contractor's cathodic protection specialist has tested and verified proper installation of all cathodic protection facilities, the cathodic protection specialist and Engineer will energize, test, and adjust the system. Any construction defects identified during these tests must be located and corrected by the Contractor.

END OF SECTION 26 42 00

SUMMARY SHEET

Section name: TEST

Section number: 26 42 01

Prepared by: Paj Hwang

Reviewed by: Paj Hwang Date

Date Issued: July 2023

Description: SPU Design Standards and Guidelines (DSG)

Revision #	Date	Paragraph(s) revised
1	06/01/10	Insert
2	1/1/2018	
3	12/4/2020	
4	7/31/2023	

WARNING: The standards and guidelines do not relieve licensed engineers from their responsibilities as outlined by the code of ethics and rules of practice. All specifications require editing and review by the project's licensed engineer and must be tailored to the conditions and needs of the project. The guidelines provide policy, clarity, and advice on how design should be conducted by and for Seattle Public Utilities. However, it remains the responsibility of the licensed engineer to properly interpret and apply the guidelines as appropriate to meet the needs of the project. If these standards and guidelines contain any contradictions with other standard engineering practices, the licensed engineer is responsible for identifying and resolving them.

This Section covers the work necessary to furnish and install test stations to provide for monitoring of system performance. Both in-ground, at grade and above ground post mounted are described in this specification.

Note: All specifications are edited for project-specific requirements.

PART 1 GENERAL

1.1. RELATED DOCUMENTS

- A. Drawings and general provision of the Contract, including General and Supplementary Conditions and Divisions 01 Specifications Sections, apply to this Section, including:
 - 1. Section 01330, Submittals.
 - 2. Section 16640, Impressed Current Cathodic Protection System.

1.2. SUMMARY

- A. Section includes:
 - 1. This Section covers the work necessary to furnish and install test stations to provide for monitoring of system performance.

1.3. DEFINITIONS

- A. The following definitions are used throughout the Bid Documents:
 - 1. Ferrous Metal Pipe: Any pipe made of steel or iron, or pipe containing steel or iron as a principal structural material, except reinforced concrete pipe.
 - 2. Foreign Owned: Any buried pipe or cable not specifically owned or operated by the Owner.
 - 3. Lead, Lead Wire, Joint Bonds Cable: Insulated copper conductor; the same as wire.
 - 4. Electrically Continuous Pipeline: A pipeline which has a linear electrical resistance equal to or less than the sum of the resistance of the pipe plus the maximum allowable bond resistance for each joint as specified in this section.
 - 5. Electrical Isolation: The condition of being electrically isolated from other metallic structures (including, but not limited to, piping, reinforcement, casings, etc.) and the environment as defined in NACE Standard RP0169-83.

1.4. SUBMITTALS

- A. Provide catalog cuts and other information for all materials that show compliance of those materials with these Specifications. Equipment data sheets must include manufacturer's name and product model number:
 - 1. Clearly identify all optional accessories provided.
 - 2. Cross-out options not being provided.

1.5. QUALITY ASSURANCE

- A. Provide a cathodic protection specialist as specified in Section 26 42 00, Impressed Current Cathodic Protection System.

1.6. SITE INFORMATION

- B. All cathodic protection test stations are as indicated on drawings.

PART 2 PRODUCTS

2.1. GENERAL

- A. The use of a manufacturer's name and model or catalog number is for the purpose of establishing only the standard of quality and general configuration desired. Products of other manufacturer's will be considered.

2.2. MATERIAL SUPPLIERS

- A. Suppliers listed below can usually supply the types of materials specified in this Section. Alternate suppliers will be considered, subject to approval of the Engineer.

- 1. Test Stations and wiring:

- a. Farwest Corrosion Control, Everett, WA.
- b. Mesa Products, Inc., Tulsa, OK.
- c. Norton Corrosion Limited, Woodinville, WA.

2.3. WIRES FOR TEST STATION CONNECTIONS

- A. General: Installation of conductors must comply with current NEC and NEMA WC 3-80, WC 5-73.
- B. Test Stations: Single-conductor, No. 10 AWG stranded copper with 600-volt XHHW, RHW, RHH, TW, or THWN insulation and single conductor, No. 12 AWG and No. 6 AWG stranded copper with 600-volt HMWPE insulation.
- C. Insulation colors must be as shown on the drawings and consistent throughout the entire installation.

2.4. CATHODIC PROTECTION TEST STATION

- A. Reference Section 9-30.9 – Electrolysis Test Station.
- B. In Ground, at grade per City of Seattle Std. Plan 360 , 363, and Reference Section 9-30.9 – Electrolysis Test Station, or as shown in the drawings.

2.5. PERMANENT REFERENCE ELECTRODES

- A. Reference Section 9-30.9 (5) – Zinc Reference Electrodes
 - 1. Permanent reference electrode must come with continuous, no breaks or splices, #10 yellow AWG RHW wire that is of sufficient length to reach test station location with 3 ft of slack.

2.6. CONDUIT, LOCK NUTS, AND STRAPS

- A. Rigid Galvanized Steel Conduit and Fittings: Hot-dipped galvanized meeting the requirements of ANSI 80.1, ANSI 80.4, UL and the NEC. Set-screw type fittings must not be used.
- B. PVC Conduit and Fittings: Schedule 80, UL listed for direct burial. Conduit and fittings must meet the requirements of NEMA TC and TC3, Federal Specification W-C-1094, UL, and NEC.
- C. Conduit must be sized in accordance with the NEC and must be of such size and so installed that conductors may be drawn in without injury or excessive strain.
- D. Lock nuts, Two-Hole Straps, and Miscellaneous Hardware: Hot-dipped galvanized steel.
- E. Conduit Bushings: Threaded plastic or plastic-throated galvanized steel fittings.

2.7. THERMITE WELD MATERIALS

Reference Section 9-30.11.

2.8. WIRE CONNECTORS

- A. One-piece, tin-plated crimp-on lug connector as manufactured by Burndy Co., Thomas and Betts, or approved equal.

2.9. COMPRESSION CONNECTORS

- A. Compression connectors for wire splicing must be "C" taps made of conductive wrought copper, sized to fit the wires being spliced, Burndy Type "YC" or approved equal.

2.10. ELECTRICAL TAPE/HIGH VOLTAGE RUBBER SPLICING TAPE

- A. Linerless rubber high voltage splicing tape and vinyl electrical tape suitable for moist and wet environments, such as Scotch 130 C and Scotch 88 as manufactured by 3M Products, or approved equal.

PART 3 EXECUTION

3.1. GENERAL

- A. Whenever the requirements of the Specifications or drawings exceed those of the codes or manufacturer's instructions, the requirements of the Specifications or drawings must prevail. Where a larger size or better grade of material or a higher standard of workmanship is required, the most stringent requirement must apply.

3.2. TEST STATION INSTALLATION

- A. The general locations of the test stations are shown on the drawings. Coordinate with Owner and record the installed location within 5 ft of the planned location for accommodation of actual site conditions as such (tree roots, etc.).
- B. Test wires must be attached to the pipe as specified under WIRE CONNECTIONS, this Section.
- C. Test and reference electrode wires must be buried a minimum of 36 inches below finished grade in the street right-of-way.
- D. Wire connections to test station terminals must be with crimp-on spade lug terminals, except where solid wire is specified.
- E. Install concrete marker post at each test station location. Marker posts must extend 3 ft below grade. The marker posts must show test station and pipeline station. Locate marker post at the edge of the SPU right-of-way or where designated by the Engineer.

3.3. REFERENCE ELECTRODE INSTALLATION

- A. Prepare reference electrode with specified backfill in accordance with the manufacturer's written instructions. Place reference electrode within the pipeline trench excavation 6 inches offset from the pipe, below the springline in a vertical or horizontal position. Where the Owner's pipeline crosses foreign pipelines, place the electrode between the foreign and Owner's pipeline. Reference electrodes must be backfilled with native trench material. Terminate wires in the test stations.

3.4. WIRE CONNECTIONS

- A. The electrical connection of copper wire to steel, ductile and cast iron surfaces must be by the thermite weld method. Observe proper safety precautions, welding procedures, thermite weld material selection, and surface preparation as recommended by the welder manufacturer. Assure that the pipe or fitting wall thickness is of sufficient thickness that the thermite weld process will not damage the integrity of the pipe or fitting wall or protective lining.
- B. Before the connection is made, the surface must be cleaned to bare metal by making a 2-inch by 2-inch window in the coating, and then filing or grinding the surface to produce a bright metal finish. The use of a resin, rubber, or shellac impregnated type grinding wheels will not be acceptable. The prepared metal surface must be dry.
- C. Wire sleeves must be installed on the ends of the wires before welding to the metal surface. Thermite welding must be performed in strict accordance with the manufacturer's written instructions. After the weld connection has cooled, remove slag and physically test wire connection by striking a glancing blow with a 16oz. hammer; remove and replace any defective connections.
- D. Install a prefabricated thermite weld cap over each completed connection. All exposed metal surfaces not covered by the thermite weld cap must be repaired in accordance with the coating manufacturer's recommendations. All damage to the pipe lining must be repaired in accordance with the lining applicator's recommendations. Thermite weld cap must be adhered to pre-primed and tack dry surface in accordance with the manufacturer's instructions.

3.5. WIRE INSULATION REPAIR

- A. Wires must be handled with care. Splices for new underground wires will not be allowed. Splices for damage to the wire insulation must be required by spirally wrapping (50 percent overlap, minimum) with two coats of high voltage rubber splicing tape and two layers of vinyl electrical tape. Wire splices must be made with suitable sized compression connectors as specified under PRODUCTS, this Section, or mechanically secured and soldered with rosin cored 50/50 solder. Compression connectors must be made with the manufacturer's recommended compression tool. All splices must be approved by the Engineer.

3.6. TEST EQUIPMENT

- A. Before construction begins, the Contractor must obtain the test equipment necessary for electrical continuity testing as specified under ELECTRICAL CONTINUITY TESTING and the following test equipment.
 - 1. A Model RF-IT radio frequency insulator tester, as manufactured by Tinker & Razor, San Gabriel, CA; or approved equal.
 - 2. A Model 87 Digital Multimeter with case and test leads, as manufactured by Fluke Corporation, Everett, WA; or approved equal.
 - 3. Two Model "Stealth 3" (SRE-010-CPY portable) copper sulfate reference electrodes as manufactured by Borin Manufacturing, Bel Air, CA; or approved equal.
- B. The test equipment must be stored at the project site for the Contractor's use and must be maintained in accurate, working condition at all times. The test equipment must be available to the Engineer for testing purposes.

3.7. INSULATED JOINT TESTING

- A. The Contractor's cathodic protection specialist must test each insulated joint after assembly. All damaged or defective insulation parts must be replaced by the Contractor.

3.8. TESTING

- A. After the Substantial Completion Date, the Contractor's cathodic protection specialist must test the pipeline to ensure proper installation and operation of the test stations. Any construction defects identified during testing must be located and corrected by the Contractor. These tests must be made in the presence of the Engineer. Provide the Engineer with three days advance notice before beginning tests. All test data must be recorded and submitted to the Engineer.
- B. Test stations must be checked as follows:
 1. Pre-test all reference cells in water to ensure correct readings.
 2. Test all test station wire connections prior to AND after backfill AND prior to any required paving.
 3. Test after final termination and record values as "native" readings prior to energization of the cathodic protection systems.

END OF SECTION 26 42 01