SECTION 16640

CORROSION CONTROL FOR BURIED PIPE

PART 1 - GENERAL

1.01 DESCRIPTION

A. This section addresses the materials, installation and testing for basic corrosion control and monitoring facilities on buried metallic piping. Materials include herein are: test and bond stations, simple sacrificial anode installations, wire and cable, alumino-thermic welds, insulating flange kits, supplemental linings at insulators and marker posts.

1.02 RELATED SECTIONS

The Work of the following Sections also apply to the Work of this Section. Other Sections, not referenced below, shall also apply to the extent required for proper performance of this Work.

A. Section 01300 – Record Drawings and Submittals

B. Section 02223 – Trenching, Backfilling and Compaction

C. Section 09868 – Cold Applied Wax Tape Coating

D. Section 09900 – Painting and Coating

1.03 CONTRACTOR SUBMITTALS

A. Submit shop drawings in accordance with Section 01300.

B. Submit manufacturer's catalog data and descriptive literature for all material items listed below and included in the project. Show dimensions and materials of construction by specification reference and grade where applicable.

PART 2 - MATERIALS

2.01 TEST STATIONS

A. Post Mounted Test Boxes:

1. Enclosure: Post-mounted enclosures shall be constructed of one piece molded fiberglass and conform to NEMA 4X. The fiberglass-reinforced resins shall be chemically resistant to a wide range of corrosive atmospheres. It shall have a hinged cover with quick-release lockable latches and a seamless foam gasket. All hardware shall be stainless steel. Hinges shall be corrosion resistance polyester or stainless steel piano hinge. Size as follows unless noted otherwise on the Drawings:

No. of Wires	Size (inside)	Acceptable Product
2 or 3 wires	5.5x4.0x5.0”	Hoffman A-645JFGQRR
4 or 5 wires	7.5x6.0x5.28”	Hoffman A-865JFGQRR

2. Panel: The mounting panel shall be fiberglass, micarta or laminated phenolic sheet cross-laminated for resistance to warpage and weathering. Minimum panel thickness shall be 3/16-inch. Panel shall be mounted off of the back of the enclosure to allow sufficient access to make up wire terminals.

3. Components: All terminal lugs shall be solid brass. Provide a properly sized terminal lug for all wires. See detail drawings for wiring configuration and wire labels.

4. Post: Post shall be seasoned, construction heart garden grade redwood, 4 inches by 4 inches by 5 feet long, and surfaced on four sides. Cut a 3/4-inch chamfer in all 4 top edges and paint per Section 09900 using System No. 60. Color shall be white and green or as approved by the Owner.

5. Conduit: 2-inch diameter galvanized rigid steel conduit per UL 6 approximately 4-feet long with long radius sweeps. Fittings shall be galvanized rigid steel per UL 514.

6. Brass Tags: Wire identification tags shall be 1-1/2 inch diameter, 18 Ga. brass discs with a 3/16-inch diameter hole and die stamped with 1/4-inch characters. Tags shall be attached to test wires with un-insulated AWG No. 14 solid copper wire. Tag legend shall be as indicated in the drawings or as directed by the Owner.

7. Concrete Pad: ASTM C-94 ready mix concrete.

2.02 PREPACKAGED MAGNESIUM ANODES

A. Magnesium Anode (High Potential): anodes shall be high potential prepackaged magnesium alloy ingot of the following chemical composition:

Aluminum	0.010%
Manganese	0.50 to 1.30%
Copper	0.02% MAX
Nickel	0.001% MAX
Iron	0.03% MAX
Other	0.05% Each or 0.3% MAX Total
Magnesium	Remainder

B. Anode Weight: the ingot weight of prepackaged magnesium anodes shall be 48 pounds. The anode ingot shall have a trapezoidal cross section and be approximately 32 inches long. Other anode ingot weights (with different cross sections and dimensions) may be specified on the Drawings or may be approved by the Owner.

C. Anode Backfill: Each magnesium anode shall be prepackaged in a permeable cloth bag with a backfill of the following composition:

Gypsum	75%
Powdered Bentonite	20%

Anhydrous Sodium Sulfate 5%

D. Backfill grains shall be capable of 100 percent passing through a 100-mesh screen. The backfill shall be firmly packed around the anode by mechanical vibration to a density, which will maintain the magnesium ingot in the center of the cloth bag and surrounded by at least one inch of backfill.

E. Prepackage Weight: The total packaged weight of 48-pound (ingot weight) magnesium anodes and backfill shall be approximately 105 pounds. The cloth bag diameter is 8 inches. The packaged weight and diameter of other anode sizes shall be as indicated on the Drawings or as approved by the Owner.

F. Anode Lead Wire: Anode lead wire shall be AWG No. 12 stranded copper wire with THWN insulation conforming to UL Standard 83. Wire shall be connected to the strap core with silver solder. The connection shall be mechanically secured before soldering and shall have at least one and one-half turns of wire at the connection. The connection shall then be insulated by filling the remainder of the recess with electrical potting compound. Anode lead wire shall be of sufficient length to extend from the anode to the designated termination point without a splice. Wires with cut or damaged insulation will not be accepted and replacement of the entire lead will be required at the Contractor's expense.

2.03 SHUNTS

A. Shunts used in the anode test boxes shall be 0.01 ohms - resistance and rated at 6 amperes capacity and accurate to plus or minus 1 percent. Use Holloway Type RS shunt unless otherwise specified.

2.04 WIRE AND CABLE

A. General: All DC wires shall be stranded copper with high molecular weight polyethylene (HMWPE) or thermal plastic (THWN) insulation suitable for direct burial in corrosive soil and water conforming to UL 83 and ASTM Standards B3 or B8. HMWPE insulation shall conform to the requirements of ASTM D1248 Type 1, Class C. THWN insulation shall conform to the requirements of ASTM D2220. Wires with cut or damaged insulation will not be accepted and replacement of the entire length of wire will be required at the Contractor's expense.

B. Test Leads: Unless otherwise indicated, test wires shall be AWG No. 8 HMWPE wire. THWN wire shall be used only where specifically called out. Each test lead shall be of sufficient length to extend from the attachment to the pipe or structure to the test box without a splice.

C. Bond Wires: Bond wires shall be AWG No. 2, No. 4, or No. 6 HMWPE depending on the pipe diameter and as indicated on the Drawings or directed by the Owner. Bond wires shall be as short as possible.

2.05 LEAD WIRE CONNECTORS

A. Terminal Lugs: Terminal lugs shall be solderless, UL 486 copper or brass and sized to accommodate the wire.

B. Split-bolt Connectors: Split bolt connectors shall be UL 486 copper or brass and sized to accommodate the lead wire and shunt being used.

2.06 INSULATING FLANGE KITS

A. General: Insulating flange kits shall consist of Type E, full-face gaskets, insulating sleeves and double washers (steel and dielectric) on each end. All insulating material shall be of the type designated by the manufacturer as suitable for the operating temperature and pressure of the service. If the insulating flange kit is not compatible with planned tapping valve, an additional flanged spool or a prefabricated insulating joint will be required.

B. Gaskets: Insulating gaskets shall be dielectric neoprene-faced phenolic.

C. Sleeves: Use 1/32-inch thick G10 epoxy glass tube material as per NEMA LI-1. Sleeves shall be full-length except for installation on threaded studs where half-length sleeves are required. For installation on threaded bolts, i.e., at butterfly valve flange bonnets and bases, the sleeves shall be half-length.

D. Washers: Insulating washers shall be 1/8-inch thick G10 epoxy glass sheet material.

E. Steel Washers: Steel washers shall be 1/8-inch thick cadmium plated or zinc plated carbon steel.

2.07 WAX TAPE WRAP

A. Surfaces Requiring Wax Tape: All buried piping system surfaces not coated with the primary pipe coating such as flanges, valves, couplings, insulating flanges, adapters, uncoated pipe spools or specialty fittings.

B. Material and Application Standard: Petrolatum wax tape coating system per Section 09868.

2.08 ALUMINO-THERMIC WELD KITS AND WELD COATING

A. Weld Kits: Wire-to-pipe connections shall be made by the alumino-thermic welding process. Weld charges and mold size shall be as specified by the manufacturer for various pipe sizes and surface configurations. Weld charges for use on cast and ductile iron are different from those used on steel. Care should be taken during installation to be sure correct charges are used. Welding charges and molds shall be the product of a manufacturer regularly engaged in the production of such materials. Weld charges for steel pipelines have green caps. Weld charges for cast or ductile iron have orange caps.

B. Weld Cap Primer: Weld cap primer shall be an elastomer-resin based corrosion resistant primer for underground services such as Royston Roybond Primer 747 or Owner approved equal.

C. Weld Caps: Alumino-thermic welds shall be sealed with a pre-fabricated plastic cap filled with formable mastic compound on a base of elastomeric tape. Weld caps shall be Royston Handy Cap 2 or Owner approved.

D. Weld Cap Overcoating: Weld caps and the surrounding area shall be overcoated with a cold-applied, black, thixotropic material containing plasticized coal tar pitch, solvents, and

special fillers per MIL-C-18480A such as Protecto Wrap 160/160H, Carboline 330M, Tape-Coat TC Mastic or 3M Scotch Clad 244. Apply to at least 20 mils thickness.

2.09 PLASTIC WARNING TAPE

A. Plastic warning tape shall be run in the wire trench at a depth of 12-inches and above each buried wire. The warning tape shall be 3 inches wide and shall have a printed warning - "Caution - Cathodic Protection Cable Buried Below" or similar.

2.10 MORTAR

A. Mortar used to repair concrete coated pipe after attachment of bond or pipe test lead wires shall be the fast drying, non-shrink type.

PART 3 - EXECUTION

3.01 GENERAL

A. Except as directed differently below, the installation of corrosion control and monitoring facilities shall conform to NACE Publication RP0169 - Recommended Practice, Control of External Corrosion on Underground and Submerged Metallic Piping Systems and NACE RP0286 Electrical Isolation of Cathodically Protected Pipelines.

3.02 TEST BOXES

A. Post Mounted Test Boxes:

1. Location: locate redwood post directly above the pipeline, if possible, but not in a roadway or in a location that clearly obstructs existing access or is particularly susceptible to damage. The Owner shall approve test station locations.

2. Post: Use white paint for the finish coats and green paint for the top 4 inches of the chamfered end. Excavate a 16-inch diameter by 2-foot deep hole. Center the post and test box in the hole and fill the hole with concrete. The concrete shall be Class C in accordance to the "Greenbook" Section 201.

3. Test box and Conduit: Connect 2-inch galvanized conduit to the anode test box with a threaded flange and collar connection. Attach test box to the redwood post using mounting brackets and threaded fasteners or wood screws through the back of the test box. Attach conduit to the post with conduit clamps and wood screws if necessary. Insert all test leads in the galvanized conduit and run into test box prior to setting the post in concrete.

4. Wire Identification: Brass identification tags shall be securely attached to each of the wires in the test box. Tags shall be stamped with the size-material-service of the pipe to which the test leads are attached. For example 18"-STL-PW. Brass tags on wires in insulating flange test boxes shall be stamped with the additional identification of "N", "S", "E", or "W" for North, South, East or West to indicate on which side of the insulating flange the wires are attached. Attach tags with bare No. 14 copper wire.

5. Concrete Footing: Footing shall be 16-inch diameter by 24-inches deep. Dome concrete slightly to prevent ponding water next to wood post.

3.03 INSTALLING MAGNESIUM ANODES

A. General: Anodes shall be installed at locations as shown on the Drawings or as directed by the Owner. Care shall be taken to ensure that the cloth bag is not damaged and no backfill material lost during installation. Each magnesium anode shall be centered in the cloth bag. It may be necessary to re-center the anode in the cloth bag by rolling it on the ground prior to installation. Each magnesium anode shall be lowered into the hole using a sling or rope and placed vertically at the bottom of the hole. Do not lower, transport, handle or lift the anode by the lead wire.

B. Primary Excavation Method: Prepackaged magnesium anodes shall be installed in a vertical augured hole of 12-inches in diameter. The depth of the hole shall be 12 feet as measured from the finish surface to the bottom of the anode unless otherwise specified.

C. Alternate Excavation Method: If the 12-foot depth cannot be obtained or if vertical auguring cannot be accomplished due to hard rock, the Owner's representative shall be notified for possible adjustment to the designed depth, position, and orientation of the anodes. Backhoe excavations must be approved by the Owner.

D. Relative Position: Anode beds shall be offset from steel or ductile iron pipe a minimum of 10 feet unless otherwise indicated on corrosion protection detail drawings or approved by the Owner. At no time shall an anode be installed outside of the pipeline right-of-way or Owner's easement.

E. Anode Soaking (Augured Holes): Once the prepackaged anode is in the hole, water shall be poured into the hole so that the anode is completely covered with water. Allow to soak for at least 15 minutes. Stone-free native soil shall then be used to backfill the anode hole. Do not use imported sand for backfilling. The anode hole shall be backfilled in stages and carefully tamped to ensure that no voids exist around the bag and that the bag and anode lead wire is not damaged. After backfill is level with the top of the anode, a minimum of 15 gallons of water shall be poured into the hole to completely saturate the soil backfill. More water shall be added if it is suspected that the backfill is not completely saturated. Care must be taken to avoid damage to the anode and anode lead wire.

F. Anode Soaking (Backhoe Installations): Prepackaged must be pre-soaked in water for at least 15 minutes before installing in the trench. After covering the anode with native, rock-free soil (approximately 3 inches over the anode) the anode and initial backfill shall be further soaked with 15 to 20 gallons of water and allowed to soak for 15 minutes. The remainder of the trench is backfilled with native soil.

G. Lead Wire: Anode lead wire shall be long enough to reach from the anode to the anode test box without a splice. Anode lead wires shall be trenched a minimum of 36-inches deep and terminate individually in the appropriate anode test box. Care shall be taken not to damage the lead wire thought the installation process.

H. Wire Tags: Anode wires are not tagged.

3.04 INSTALLING ANODE LEAD WIRES

A. Wire Trenching: All buried anode and test wires shall be installed at a minimum depth of 36 inches. The bottom of the finished trench shall be sand or stone-free earth. The first three inches of sand backfill material shall be placed directly on the wires. The remainder of the trench shall be backfilled with stone-free earth. Care shall be taken when installing wire and backfilling trench so that insulation is not broken, cut, nicked, or bruised. If wire insulation is damaged during installation, the wire and anode shall be replaced unless wire splices or insulation repairs are approved by the Owner. Anode replacement shall be at the Contractor's expense. Plastic warning tape shall be installed approximately 12 inches below finished grade.

B. Wire Splicing and Insulation Repairs: Neither splices nor insulation repairs are allowed unless specifically approved by the Engineer.

3.05 WIRE AND CABLE

A. General: No less than two test wires shall be attached to the pipe at each designated test site. All test wires shall terminate in a test box without a splice. A minimum of 18 inches of slack wire shall be coiled at the wire-to-pipe connection and in at-grade test boxes for each test wire. At post-mounted test stations slack wire shall be provided inside the box to the extent possible and with one 8-inch diameter loop at the below-grade entrance to the conduit.

B. Connection to Pipe: Connections of copper wire to the pipeline shall be made with alumino-thermic weld charges or by brazing. Welding charges shall be the product of a manufacturer regularly engaged in the manufacture of the material. Manufacturer's recommend cartridge size and type shall be used. Each weld shall be installed, tested and coated as described below.

1. Preparation of Wire: Use a cutter to prevent deforming wire ends. Remove only enough insulation from the wire to allow the weld connection to be made. Do not use a hacksaw for cutting.

2. Preparation of Metal: Remove all coating, dirt, grime and grease from the metal pipe at weld location by wire brushing and/or use of suitable safe solvents. Clean the pipe to a bright, shiny surface free of all serious pits and flaws by use of mechanical grinder or a file. The area of the pipe where the attachment is to be made must be absolutely dry. Failure to provide a dry surface for welding will result in a poor quality weld and could result in serious injury to the workman. Do not cut reinforcing rods when preparing metal surface for wire attachment.

3. Attachment of Wire to Pipe: The attachment of copper wire shall be made using an alumino-thermic weld as shown on the Approved Plans. The wire is to be held at a 30° to 45° angle to the surface when welding. Only one wire shall be attached with each weld.

4. Testing of All Completed Welds: As soon as the weld has cooled, the weldment shall be tested for strength by striking a sharp blow with a two-pound hammer while pulling firmly on the wire. All unsound welds are to be re-welded and re-tested. All weld slag shall be removed from the weldment.

5. Coating of All Completed Welds: Thoroughly clean by wire brushing the area to be coated. The area must be completely dry. Apply the weld cap primer and the weld cap. Overcoat the weld cap with a bituminous mastic coating material in accordance with the manufacturer's recommendations. Completely coat the weld, all bare pipe surfaces around the weld and any exposed copper wire. Allow sufficient time to dry prior to repair of the mortar coating on steel pipe.

6. Mortar Repair: On mortar coated pipe, the mortar coating shall be repaired after the bituminous weld coating has dried, using fast-setting, non-shrinkable mortar to restore the original outside diameter of the pipe at each weld location.

C. Wire Trenching and Backfill:

1. Depth: All buried horizontal test lead runs shall be installed at a minimum depth of 36 inches.

2. Backfill: The bottom 2 inches of the finished trench shall be sand or stone-free earth. The first three inches of the backfill shall be sand or stone-free earth placed directly on the wires. The remainder of the trench shall be backfilled with native earth with a maximum stone size of 2 inches and compacted as specified in Section 02223.

3. Damaged Wire: Care shall be taken when installing wire and backfilling trench so that insulation is not broken, cut, nicked, or bruised. If wire insulation is damaged during installation, it shall be replaced completely at the Contractor's expense.

4. Warning Tape: Plastic warning tape shall be installed over all wire runs 12 inches below grade.

D. Installing Identification Tags

1. Characters: Tags shall be stamped with Owner, size, material and service. For example a 24-inch CML&C steel water line shall be stamped "Owner, 24"CML&C, W". An 8-inch ductile iron reclaimed water line would be tagged "Owner, 8"DIP, RW". Anode lead wires are not tagged. Tags on wires on insulating flanges shall be stamped with "N, E, S or W" indicating which side of the insulating joint to which the wires are attached. The character size shall be 1/4-inch high.

2. Attachment to Wire: Identification tags shall be securely attached to each test wire in the test box with a bare No. 14 copper wire. Do not use plastic or nylon ties.

E. Wire Splices or Repairs

1. Approval: No wire splices or insulation repairs shall be made unless approved by the Engineer.

2. Splices: The minimum amount of insulation shall be removed from each wire end. Brass crimp or split-bolt connectors shall be used. The splice shall be encased in a plastic mold filled with insulating resin such as 3M Scotchcast splice kits.

3. Insulating Repairs: Depending on the severity of the insulation damage, repairs shall be made with electrical tape or with a splice kit as determined by the Engineer.

4. Inspection: All splices and insulation repairs shall be inspected by the Engineer before they are buried.

3.06 CONTINUITY BONDING:

A. General: All joints on buried metallic pipe shall be metallically continuous by welding or bonding. Joints to be bonded include all unwelded pipe joints and mechanical joints including flanges (except insulating flanges), valves, couplings, adapters and special fittings. All bonding shall be done with single conductor, stranded copper jumper wires with HMWPE insulation. Bond wires shall be as short as possible with only minimal slack. All pipe reaches with one or more unwelded joints (or one or more bonds) will be tested for continuity.

B. Pipe Joints: At least two wires are required for each steel or ductile iron pipe bond. Two wires shall be installed unless otherwise specified. Three wires may be required at valves, couplings, special fittings and across unwelded joints on pipe larger than 24-inches. Bond wire sizes may be No. 2, 4 or 6. Use No. 4 bond wires unless indicated otherwise in the Approved Plans.

C. Mechanical Joints and Fittings: All flanges and in-line fittings (valves, couplings, etc.) shall be completely bridged by at least two bond wires. Three wires may be required on fittings larger than 24-inches. One additional No. 6 HMWPE wire is required from the pipe (on either side) to the fitting. Bond wire sizes may be No. 2, 4 or 6. Use No. 4 bond wires unless indicated otherwise on the Drawings.

D. Wire Attachment Method: Bond wire attachment, testing and subsequent coating of the welds shall be as specified in paragraph 3.5, B.

E. Wire Attachment Location: Bond wires can either be attached to the pipe or pipe cylinder directly of to the outside edges of flanges that are welded to the pipe. Bond wires shall not be attached to valve bodies, but instead to the flange of the valve.

3.07 INSULATING FLANGE KITS

A. Flange Kits: Insulating kits shall be installed as shown on the Drawings and as recommended by the manufacturer. Moisture, soil, or other foreign matter must be carefully prevented from contacting any portion of the mating surfaces prior to installing insulator gasket. If moisture, soil, or other foreign matter contacts any portion of these surfaces, the entire joint shall be disassembled, cleaned with a suitable solvent and dried prior to reassembly.

B. Spool Assembly: All direct buried insulating kits, greater than 20-inches in diameter, shall be pre-installed and tested on the pipe spool prior to installing the spool in the ditch. If possible, all smaller size direct buried insulating kits shall be similarly pre-installed and tested.

C. Handling of Gasket: Care shall be taken to prevent any excessive bending or flexing of the gasket. Creased or damaged gaskets shall be rejected and removed from the job site.

D. Alignment: Alignment pins shall be used to properly align the flange and gasket.

E. Bolt Tightening: The manufacturer's recommended bolt-tightening sequence shall be followed. Bolt insulating sleeves shall be centered within the insulation washers so that the insulating sleeve is not compressed and damaged.

F. Testing: All insulating flanges must be tested by a qualified Corrosion Technician or Engineer and accepted by the Owner. All buried insulating flanges must be tested prior to wax tape wrap coating and backfilling. The assembled flange shall be tested as described below.

G. Wax Tape Coating: After testing and the Engineer's acceptance, the insulating flange shall be fully wrapped with petrolatum wax tape, including individual wrapping of all bolts, nuts, and washers, and irregular surfaces, per Section 09868.

PART 4 - SYSTEM TESTING

4.01 TEST LEADS AND BOND WIRES

A. Responsibility: The Contractor shall be responsible for testing all test leads and bond wire welds.

B. Test Method: All completed wire connection welds shall be tested for strength by striking the weld with a sharp blow with a 2-pound hammer while pulling firmly on the wire. Welds failing this test shall be re-welded and re-tested. Wire welds shall be spot tested by the Engineer. After backfilling pipe, all test lead pairs shall be tested using a standard ohmmeter or resistance meter for broken welds. Bond wires shall be tested through continuity testing described below.

C. Acceptance: The resistance between each pair of test leads shall not exceed 150% of the total wire resistance as determined from calculations based on published wire resistance data and an estimate of test wire length.

4.02 ANODE INSTALLATIONS

A. Responsibility: The Contractor must provide the proper rated potential anode, sufficient anode lead wire length and the proper anode hole depth. The Owner shall test each installed anode for wire connection integrity and for open-circuit potential.

B. Notification: The Contractor shall notify the Owner at least 5 days in advance of the start and completion of the anode installations, including anodes and test stations.

C. Cathodic Protection Performance Test Method: The performance of the cathodic protection system shall be tested by the Engineer. The testing shall include: measurement of all open-circuit anode potentials; pipe-to-soil potentials at each test station and other locations as necessary before the anodes are connected; initial anode currents after connecting anode leads to the pipe leads; and the pipe-to-soil potential at each previously tested site with all anodes connected. Pre- and post cathodic protection potentials at midpoints between anode beds are required as necessary to verify that the pipeline is fully protected. Adequate protection shall be as defined in NACE RP0169.

D. Field Report: All system deficiencies shall be listed and described in one or more field test reports and presented to the Contractor for repairs.

E. Acceptance: The system will be accepted if all anodes, test stations, and supporting facilities are installed properly. Cathodic protection performance, with the exception of materials and installation deficiencies, is not the Contractor's responsibility.

4.03 WIRE TRENCHING

A. Responsibility: The Engineer, at his or her discretion, shall inspect wire trenches and backfill material and methods.

B. Test Method: The depth, trench bottom padding and backfill material shall be visually inspected prior to backfilling.

C. Acceptance: Conformance with project specifications.

4.04 INSULATOR TESTING

A. Responsibility: Insulating flanges shall be inspected and tested by the Owner Corrosion Engineer or Corrosion Technician. Buried insulators must be tested and approved prior to application of wax tape and backfilling. Large diameter insulators shall be tested on the spool prior to installation in the ditch.

B. Test Method: The assembled flange shall be tested with an insulator testing device (i.e., Gas Electronics Model 601 Insulation Checker) specifically designed for this purpose. Additionally, the pipe-to-soil potential, using a high impedance voltmeter and suitable reference cell, shall be measured on each side of the insulator after installation in the trench but before backfilling. Potential testing can only be done on piping that has been installed in the ditch.

C. Acceptance: The installation shall be considered complete when the insulator testing device indicates that no shorts or partial shorts are present and when the potential tests indicate greater than 20-millivolt pipe-to-soil potential difference across the flange. (Note that this test may not be valid if the pipe on each side of the insulator is in contract through interconnection piping or through contacts to the electrical grounding system.) If shorts are detected the Contractor shall assist the Owner in finding partial shorts or shorted bolts. All disassembly and re-assembly necessary to gain the acceptance of the Owner shall be done at the Contractor's expense.

4.05 PIPELINE CONTINUITY

A. Responsibility: The Owner's Corrosion Engineer shall test the continuity of all sections of buried pipe that contain non-welded pipe joints or mechanical joints or fittings. All such joints are required to be bonded per this Section.

B. Test Method: Resistance shall be measured by the linear resistance method. A direct current shall be impressed from one end of the test section to the other (test station to test station) using DC power supply (battery). A voltage drop is measured for several current levels. The resistance (R) is calculated using the equation $R = dV/I$, where dV is the

voltage drop and I is the current. The resistance shall be calculated for three or four different current levels.

C. Acceptance: Acceptance is reasonable comparison of the measured resistance with the calculated or theoretical resistance. The measured resistance shall not exceed the theoretical resistance by more than 130 percent. The Contractor shall submit calculations of the theoretical resistance and the measured resistance for each section of pipe tested.

D. Deficiencies: If discontinuity or high resistance is found between sections of pipe tested, it is the Contractor's responsibility to locate, excavate, and repair all bonds that are found to be discontinuous. Continuity tests shall be repeated after repairs are made.

E. Discontinuities may be difficult and expensive to locate and may require several excavations to expose pipe joints and attach temporary test leads for progressive continuity testing. Accordingly, the Contractor shall exercise due care in installing continuity bonds and should schedule continuity testing as early as possible so that discontinuity location and repairs, if necessary, do not conflict with surface improvements.

4.06 TEST STATIONS

A. Responsibility: The District's Representative will inspect all test station installations for compliance with this specification. The Contractor's Subcontractor installing the test stations will test all wires for continuity and proper connection, to be witnessed by a District Representative.

B. Test Method: Test stations will be visually inspected. Wire continuity will be tested by potential and resistance measurements.

C. Acceptance: Installation in accordance with this specification and good workmanship and verification that all wires are properly connected.

4.07 COATING AND SUPPLEMENTARY LINING

A. Responsibility: The Engineer shall inspect all completed wax tape wrapping and supplementary linings at insulators for compliance with these specifications prior to backfilling.

B. Test Method: Inspection shall be visual.

C. Wax Tape Acceptance: Wax tape applications shall be accepted if: the application conforms with this specification; there are no voids or gaps under the wax tape; stud-ends, nuts, couplings rods and all irregular surfaces are individually wrapped such that there is complete coverage with the petrolatum material; the outer wrap is complete and tightly adhering to the wax tape; and the application is done in a good workman-like manner.

D. Supplementary Lining Acceptance: Internal supplementary linings must cover the specified length of pipe and must be well bonded to the substrate and free of voids or damage.

4.08 DEFICIENCIES

A. Deficiencies: Any deficiencies or omissions in materials or workmanship found by these tests shall be rectified by the Contractor at his expense. Deficiencies shall include but are not limited to: broken or missing test leads; improper or unclean wire trench backfill; inadequate pipeline continuity; shorted or partially shorted insulators; lack of 18-inch slack wire in at-grade test boxes; improperly mounted or located test boxes; improper wire identification; poorly applied wax tape or supplementary lining; and other deficiencies associated with the workmanship, installation and non-functioning equipment.

END OF SECTION