STANDARD SPECIFICATIONS

SECTION 13110

CORROSION PROTECTION AND JOINT BONDING

PART 1 - GENERAL

A. Description

This section describes the materials, installation and testing requirements for corrosion protection and monitoring facilities for buried piping and appurtenances. The facilities addressed below include: corrosion test stations; reference cells; insulating flange kits, casing insulators and seals; bonding for pipe and mechanical joints; alumino-thermic welds and sacrificial anodes for new water services and air/vacuum assemblies. Not included are pipeline cathodic protection requirements.

B. Related Documents

1.	District Standard Drawings:	W-21 through W-31
2.	Trenching, Backfilling, and Compacting:	02223
3.	Concrete:	03300
4.	Painting and Coating:	09900

C. Specifications and Standards

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by the basic designations only.

ANSI/ASME B16.21 (Rev 1992)	Nonmetallic Flat Gaskets for Pipe Flanges
ASTM B3-90	Soft of Annealed Copper Wire
ASTM B8-86	Concentric-Lay-Stranded Copper Conductors
ASTM B 418	Standard Specification for Cast and Wrought Galvanic Zinc Anodes
ASTM D 1248-84 (Rev 89)	Polyethylene Plastics Molding and Extrusion Materials
AWWA C-217	Wax Coating Systems for Underground Piping Systems

MIL-C-18480B	Coating Compound, Bituminous, Solvent, Coal Tar Base
NACE RP0169-96	Recommended Practice, Control of External Corrosion on Underground or Submerged Metallic Piping Systems
NACE RP0286-97	Electrical Isolation of Cathodically Protected Pipelines
NEMA LI 1 –1989 (Rev 1995)	Industrial Laminated Thermosetting Products
UL 83-80	Thermoplastic-Insulated Wires

D. Submittals

1. Manufacturer's catalog cuts including:

   a. Post-mounted test enclosure
   b. Enclosure components
   c. Redwood post
   d. Conduit
   e. At-grade test boxes
   f. Brass tags
   g. Insulating flange kits
   h. Wax tape wrap system
   i. Wire and cable
   j. Plastic warning tape
   k. Casing seals
   l. Casing insulators
   m. Zinc water service anodes

2. As-built Drawings: The contractor shall maintain as-built drawings showing the exact locations of all corrosion monitoring test stations, insulators, and wire trenching runs. Location changes from the design drawings shall be legibly indicated in red on a blue line copy of the design drawings. These drawings shall be submitted to the District's representative before the work is considered complete.

3. Test Results: The following test results shall be submitted to the District representative.

   a. Continuity test report
   b. Insulator test results
   c. Initial pipe-to-soil potential survey

4. Notification for Testing: The contractor shall notify the District representative at least five days in advance of installation of anodes and completion of wrapping of buried flanges and couplings. The contractor shall also notify the District representative when test leads, continuity bonding and test boxes are installed and ready for inspection.

PART 2 - MATERIALS

A. Test Stations

1. Post Mounted Test Boxes:

a. Enclosure: The enclosure for a post mounted shunt box shall be approximately 7.5 inches x 6 inches x 5.28 inches and suitable for mounting on a post. Enclosure shall be constructed of one piece molded fiberglass and conform to NEMA 3R. The enclosure shall be constructed of fiberglass reinforced resins that are chemically resistant to a wide range of corrosive atmospheres. The enclosure shall have non-metallic hinges and lockable quick release latches. Enclosure shall be Hoffman, Catalogue No. A-865JFGQRR or approved equal.

b. 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 space for terminal connectors.

c. Components: All terminal lugs and fasteners shall be solid brass. Provide a properly sized terminal lug for all wires. See District Standard Drawings for wiring configuration and wire labels

d. Post: Post shall be seasoned, construction heart garden grade redwood, 4 inches by 4 inches, and surfaced on four sides. Cut a ¾-inch chamfer in all 4 top edges. Posts shall be 66-inches in length.

e. Conduit: Conduit for the post mounted test boxes shall be 2-inch diameter galvanized steel approximately 4-feet long.

f. Panel Labels. All wire terminations on test station panel shall be identified by permanent marking. A self adhesive aluminum tape permanently embossed with the required identification shall be fixed to the terminal board. Identify leads using an identification device by Dymo Products Company of Augusta, Georgia or approved equal.

2. At-Grade Test Box:

a. Test Box: At-grade test boxes shall be round, pre-cast concrete with dimensions of 13-1/2-inch O.D. by 8-inch I.D. by 12-inches high, similar to Christy G5 Utility Box with a cast iron supporting ring and lid, and shall have sufficient strength to support occasional vehicular traffic. The lid shall be 11 inches O.D. and cast with the legend "CP Test" using letters not less than 1-1/2-inches high.

b. Concrete Pad: Test boxes mounted in unpaved areas shall be mounted in a reinforced 26-inch square by 4-inches thick concrete pad (Class B concrete per Section 03300). Rebar shall be No. 4. A concrete pad is not required where the test box is placed in pavement.

c. Brass Identification Tags: Wire identification tags shall be 1-1/2-inch diameter 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.

B. Insulating Flange Kits

Insulating flange kits shall contain full-face gaskets, full-length sleeves and double washers (steel and phenolic) on each end. Flange insulation kits shall consist of:

1. Insulating Gaskets: Gaskets for flanges 16-inches or greater shall be Type E fullfaced Phenolic with Rectangular Nitrile or Viton O-Ring Seal (PSI Linebacker or equal). For flanges less than 16-inches, gaskets shall be Type E fullfaced neoprene faced phenolic.

2. Insulating Stud Sleeves for Bolts: Insulating sleeves shall be 1/32-inch thick, G10 laminated glass tube. For installation on threaded studs use full length sleeves. For installation on threaded bolts, i.e., at butterfly valve flange bonnets and bases, the sleeves shall be half-length.

3. Insulating Washers for Bolts: Insulating washers shall be 1/8-inch G10 laminated glass.

4. Steel Washers Over Insulating Washer: 1/8-inch thick cadmium plated steel to be placed between the nut and the insulating washer.

C. Wax Tape External Coating

1. Wax Tape Coating: All buried non-mortar coated fittings and appurtenances such as valves, flanges, insulating flanges, couplings, etc. shall be coated with a wax tape primer and wrap per AWWA C217 and the District Standard Drawings.

2. Primer: All exposed non-mortar coated surfaces including flanges, bolts and nuts shall be prime coated with a blend of petrolatum, plasticizer, inert fillers, and corrosion inhibitor having a paste-like consistency.

3. Wax Tape: Wrap primed surfaces with a synthetic felt tape saturated with a blend of petrolatum, plasticizers, and corrosion inhibitors that is easily formable over irregular surfaces. A compatible petrolatum filler should be used to smooth over irregular surfaces.

4. Outer Covering: The primed and wax-tape wrapped flange shall be wrapped with a plastic tape covering consisting of three (3) layers of 1.5 mil, polyvinylidene chloride or PVC, high cling membranes wound together as a single sheet.

5. Protective Overwrap: The edges of flanges 18-inches in diameter and larger shall be wrapped with 10-mil pipe tape (two layers, 50% overlap) to protect wax tape during backfilling process.

D. Wire and Cable

1. 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 and shall conform to the requirements of ASTM D1248 Type 1, Class C. THWN insulation shall conform to the requirements of ASTM D-2220

2. Test Leads: Test wires shall sized as shown in the District Standard Drawings. Each test lead shall be of sufficient length to extend from the attachment to the pipe or casing to the

test box 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.

3. Bond Wires: Bond wires shall be AWG No. 2, No. 4, or No. 6 HMWPE depending on the pipe diameter and as described in the District Standard Drawing W-31. Bond wires shall have minimal slack wire at each weld but otherwise be as short as possible.

E. Alumino-Thermic Welds

1. Weld Process: Cable-to-metal connections shall be made by the alumino-thermic welding process. Weld charge size, alloy and mold size shall be as specified by the manufacturer of the weld kit for use on steel or ductile iron pipe.

2. 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 approved equal.

3. 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 approved equal.

4. Weld Coating: All buried alumino-thermic welds and weld caps shall be coated with a cold-applied fast-drying mastic consisting of bituminous resin and solvents per Mil. Spec MIL-C-18480B such as Carboline 300M, Tnemec 40-H-413, Tape-coat TC Mastic or 3M Scotch Clad 244. The minimum coating thickness shall be 25 mils (0.025 inch)..

F. Plastic Warning Tape

The plastic warning tape shall be 3 inches wide and shall have a printed warning - "Caution - Cathodic Protection Cable Buried Below" or similar.

G. Mortar

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

H. Casing Seals

Casing seals used to prevent moisture intrusion into the casing annular space shall be either a rubber link or pull-on sleeve type.

1. "Rubber link" casing seals are made of molded, solid, synthetic rubber and are connected together by corrosion resistant bolts and nuts. After the links are placed in the casing opening, the bolts are turned to create an airtight and watertight seal. These types of casing seals shall be "Link Seals" brand, or approved equal.

2. "Sleeve" casing seals are made of 1/8-inch thick, synthetic rubber. The sleeve is fastened to the exterior of the casing and carrier pipe using stainless steel strapping. These types of casing seals shall be PSI Model "C" - Custom Pull-On seals, or approved equal.

I. Casing Insulators

Casing insulators used to prevent contact between the casing and carrier pipe shall be comprised of a fusion coated, 8-inch wide steel band with 2-inch wide glass reinforced plastic runners. These types of casing insulators shall be PSI Spacer Model C8G-2, or approved equal.

J. Zinc Anodes for New Services and Air-Vacs

1. Zinc Anode: Anode shall conform to ASTM B 418, Type II and shall be a prepackaged zinc alloy ingot having a chemical composition not exceeding the following limits:

Aluminum	0.005% Max.
Cadmium	0.0000% Max.
Iron	0.0014% Max.
Zinc	Remainder

2. Anode Weight and Dimensions: Ingot weight shall be 12 pounds. Ingot dimensions shall be 1.4-inches x 1.4 inches x 24 inches.

3. Anode Backfill: Each zinc anode shall be prepackaged in a permeable cloth bag with a backfill of the following composition or installed bare and backfilled with material having the following composition.

Gypsum	75%
Powdered Bentonite	20%
Anhydrous Sodium Sulfate	5%

Backfill grains shall be capable of 100% passing through a 100 mesh screen. The backfill shall be firmly packed around the anode by mechanical vibration to density which will maintain the zinc ingot in the center of the cloth bag and surrounded by at least 1-inch of backfill.

4. Steel Core: Anode shall be cast full length with an electrogalvanized 1/4-inch diameter steel core which shall be exposed at one end for connection of the anode lead wire.

5. Anode Lead Wire: Anode lead wire shall be AWG No. 12 stranded copper wire with THWN insulation suitable for direct burial use. Wire shall be attached to the steel core with silver solder by the manufacturer. The connection shall be encapsulated in a heat-shrinkable sleeve. Anode lead wire shall be of sufficient length of 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.

PART 3 - EXECUTION

A. General

Corrosion protection and monitoring installation shall conform to NACE Publication RP-0169 (Latest Revision) - Recommended Practice, Control of External Corrosion on Underground and Submerged Metallic Piping Systems.

B. 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 is particularly susceptible to damage. The District representative shall approve test station locations.

2. Test Box and Conduit: Connect 2-inch galvanized conduit to the anode test box with a threaded screw connection. Attach conduit to the post with two galvanized pipe straps and threaded fasteners. Insert all test leads in the galvanized conduit and run into test box prior to setting the post in concrete.

3. Post: Post shall be 5-feet in length with a chamfered top. Excavate a 16-inch diameter by 20-inch deep hole. Center the post and test box in the hole and fill the hole with concrete. The concrete shall be Class B per Section 03300.

4. Wire Identification: The self-adherent identification tape shall be attached to the micarta panel at the termination point of each wire. The tape shall identify the owner-size-service of the pipe to which the test leads are attached. For example: MNWD 18" RW. For wires attached to insulating flanges, an additional "N", "S", "E", or "W" for North, South, East or West shall be included on the identification tape to indicate on which side of the insulating flange the wires are attached.

C. At-Grade Test Boxes

1. Location: The at-grade test boxes shall be installed adjacent to paved roadways behind the curb; in the sidewalk, beyond the edge of the sidewalk, or in a planter as shown in the District Standard Drawing W-21. If no curb exists, locate the test box just off the paved surface. In unpaved areas or parking lots, locate the test box directly over pipe (but not in parking spaces). The District representative shall approve all test box locations.

2. Installation: All wire shall be properly identified, with approximately 18 inches of slack wire above finish grade and coiled inside the test box. Keep the inside of the test box clear of all debris and other foreign material. Top of box shall be flush with finish grade.

3. Wire Identification: Brass identification tags shall be securely attached to each of the wires in the test box with un-insulated AWG No. 14 solid copper wire. Tags shall be stamped with the owner-size-service of the pipe to which the test leads are attached. For example: MNWD 18" RW. 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.

D. Test and Bond Wire

1. Test Wires: Test wires shall be attached to the pipe and terminate in a test box without a splice as shown in the District Standard Drawings. A minimum of 18 inches of slack wire shall be coiled at each pipe connection and in each test box for each wire.

2. Bond Wires: Two or three bond wires shall be installed on steel pipe across each buried, unwelded pipe joint or mechanical joint including valves, couplings, special fittings and flanges except insulating flanges, as shown on District Standard Drawing W-31. Bond wires shall not be attached to valve bodies, but instead to the flange of the valve.

3. 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. Only one wire shall be connected with each weld. Welds shall be no closer than 3-inches. Each completed weld shall be coated as described below.

    a. 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.

    b. 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.

    c. Attachment of Wire to Pipe: The attachment of copper wire shall be made using an alumino-thermic weld as shown on the District Standard Drawings. The wire is to be held at 30° to 45° angle to the surface when welding. One wire only shall be attached with each weld.

    d. 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.

    e. 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. For non-mortar coated pipe, extend coating 3 inches beyond weld cap. For mortar coated pipe, apply coating up to but not over mortar. Allow sufficient time to dry prior to repair of the mortar coating on steel pipe.

    f. 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.

4. Wire Trenching and Backfill

    a. Depth: All buried wiring shall be installed at a minimum depth of 24 inches.

    b. Backfill: The bottom 2 inches of the finished trench shall be sand or stone-free earth. The first 3 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. 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.

c. Plastic Warning Tape: Plastic warning tape shall be run in the wire trench at a depth of 12-inches and above each buried wire

E. Flange Insulation Kits

1. General: A four wire test station shall be installed at each buried insulating flange. Two test wires shall be installed on each side of the buried insulator according to this specification and the District Standard Drawing W-23.

2. Flange Kits: Insulating kits shall be installed as shown on the District Standard Drawing W-23 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.

3. Handling of Gasket: Care shall be taken to prevent any excessive bending or flexing of the gasket.

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

5. 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.

6. Paint Pigments: Neither aluminum, graphite, nor any other electronically conductive pigment shall be used in paints or coatings on the flanges, bolts, or washers of any insulating device.

7. Testing: All insulating flanges must be inspected, tested and approved by the Corrosion Engineer retained by the District as described in this specification section. All buried insulating flanges must be tested prior to wax tape wrap coating and backfilling.

F. Wax Tape Coating:

1. Primer: Surface shall be cleaned of all dirt, dust, and loose rust or mill scale by wire brush and by wiping with a clean cloth. The surface shall be dry. Apply primer by hand or brush. A thick coating of primer shall be worked into all crevices, around bolts and in threads, and shall completely cover all exposed metal surface. The primer should overlap the pipe coating by 3-inches minimum.

2. Wax-Tape: The petroleum wax-type can be applied immediately after primer application. Short lengths of tape shall be cut and formed completely around each individual bolt and stud-end. After all bolts are covered, the tape shall be applied circumferentially and formed by hand into all voids and spaces. There shall be no gaps or air spaces under the tape. The tape shall be applied with at least 55% overlap.

3. Outer Covering: The clear plastic outer covering shall be applied by hand such that the material conforms and adheres to the wax-tape surface. Three layers of plastic outer wrapping shall be applied.

4. Protective Overwrap: The edges of all flanges 18-inches in diameter and larger shall be wrapped with 10-mil pipe tape (two layers, 50% overlap) to protect wax tape during backfilling process

G. Casing Seals

The casing end seal ("rubber link" or "sleeve" type) shall be installed wherever a metallic pipeline passes through a steel casing in order to restrict water intrusion into the casing annular space. The casing seal shall be installed according to the manufacturer's recommendations.

H. Casing Isolation

The encased sections of metallic piping shall be electrically isolated from the casing. Use casing insulators to prevent metallic contact and ensure a minimum amount of standoff between casing and carrier pipe. Distance between spacers shall be small enough to prevent excessive sagging of the line.

I. Zinc Anodes

1. General: Where called for on the drawings, prepackaged zinc anodes shall be installed in excavated, drilled, or punched holes a minimum of 8-inches in diameter. Anodes shall be installed below the level of the service or air/vac line, with a minimum separation of 2 feet between the copper water tubing and the zinc anode maintained at all times. Anodes shall not be lowered, transported, handled, or lifted by the lead wire.

2. Location: Anode shall be installed approximately midway between pipeline and meter box.

3. Backfilling: After the prepackaged anode is placed in the hole, approximately 5 gallons of water shall be poured into the hole so that the anode is completely covered with water. Allow water to soak for 30 minutes. Stone-free native soil shall then be used to backfill the anode hole. Imported sand shall not be used for backfilling. The anode hole shall be backfilled in stages and carefully compacted to ensure that no voids exist around the bag and that the bag and anode wire are not damaged. After backfill is level with the top of the anode, another 5 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 shall be taken to avoid damage to the anode and anode lead wires.

4. Anode Lead Wire: The anode lead wire shall extend from the anode along the copper pipe to the water service or air/vac meter box. The anode lead wire shall be attached to the copper water service or air/vac riser inside the meter box using a bronze mechanical grounding clamp.

PART 4 - REQUIRED TESTING AND RECORD KEEPING

A. Test Lead And Bond Wire Welds

1. Responsibility: The contractor shall be responsible for inspection all wire insulation for damage and for testing all test lead and bond wire welds.

2. Test Method: All wire insulation shall be visually inspected. 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 District representative. After backfilling pipe, all test lead pairs shall be tested using a standard ohmmeter for broken welds.

3. Acceptance: The resistance between each pair of test leads shall not exceed 150% of the total wire resistance as determined from published wire data.

B. Test Lead Trenching And Backfill

1. Responsibility: The District representative, at his discretion, shall inspect wire trenches, backfill material and compaction methods.

2. Method: The trench depth, bottom padding, and backfill material shall be visually inspected prior to backfilling. Compaction and surface finish inspection shall be per Section 02223.

3. Acceptance: Conformance with the specifications and good workmanship.

C. Test Station Installations

1. Responsibility: The District representative shall inspect final test station installations.

2. Method: Visual inspection.

3. Acceptance: Post and at-grade test stations shall be fully installed and finished as indicated in the drawings and described in these specifications. Wire in post-mounted stations shall be connected to the panel and properly labeled. Enclosures, conduit and posts shall be fully secured. At-grade test stations shall be mounted in the pavement or concrete pad. All wires shall be of proper length and identified with brass tags stamped and attached as specified herein. All work shall be in compliance with this specification section and consistent with good workmanship.

D. Insulating Flange Kits

1. Responsibility: Insulating flanges shall be inspected and tested by the Corrosion Engineer retained by the District. Buried insulators must be tested and approved prior to application of wax tape and backfilling.

2. Method: The assembled flange shall be tested with a Gas Electronics Model 601 Insulator Checker or equivalent instrument that is specifically designed for the testing of insulating flanges. The testing shall be done in accordance with NACE RP0286-97. If a short is indicated, each bolt shall be tested to verify the integrity of each insulating sleeve before the flange is disassembled. The contractor shall provide assistance in finding any and all shorts or shorted bolts.

3. Acceptance: The installation of the insulating flange kit shall be shall be considered complete when the testing instrument indicates that no shorts or partial shorts are present. Any deflection of the meter, no matter how small, indicates a short. All disassembly and re-assembly necessary for acceptance shall be done at no additional cost to the District.

4. Retest: All repaired insulating flanges shall be re-tested as indicated above until they pass. All re-testing shall be done at no additional cost to the District.

E. Wax Tape Wrap

1. Responsibility: The District representative shall inspect all completed wax tape wrapping for compliance with these specifications prior to backfilling.

2. Method: Visual inspection.

3. Acceptance: Conformance with this specification and good workmanship. The wax tape must be tight and have no air pockets and each individual bolt, nut or coupling tie-rod must be individually wrapped. The plastic outer wrap shall be have three layers and shall be neat and tight against the wax tape.

4. Pipe Tape Overwrap: All flange 18-inches or over shall have their edges overwrapped with pipe tape as described above.

F. Pipeline Continuity Through Bonded Or Mechanical Joints

1. Responsibility: The Corrosion Engineer retained by the District shall verify the continuity of buried metallic pipe where continuity is required. All sections that contains non-welded (bonded) joints, in-line mechanical joints, i.e., flanges, valves couplings and flex joints shall be tested.

2. Method: Continuity is verified when the measured linear resistance of section of pipe being tested is approximately equal its theoretical value. 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 a DC power supply (battery). A voltage drop is measured through the test section at 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.

3. 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%. The theoretical resistance is the sum of the pipe resistance and the bond (wire or clip) resistance.

4. Deficiencies: If a discontinuity or a high resistance is found within a section of pipe that section is defective. It is the contractor's responsibility to locate, excavate, and repair or replace all bonds that are found to be damaged or missing. Continuity tests shall be repeated after repairs are made. All continuity repairs and re-testing shall be done at no additional cost to the District.

5. Test Scheduling: Continuity testing shall be scheduled as soon as possible after the pipe is installed and fully backfilled. Early testing will allow excavations and repairs to be made, if needed, before the surface is paved or finished.

G. Casing Isolation

1. Responsibility: The Corrosion Engineer retained by the District shall test all casings to verify that they are metallically isolated from the pipe.

2. Method: The casing shall be considered fully isolated if the difference between the structure-to-soil potential of the casing and the pipe is more than 30 millivolts. If this potential difference is less than 30 millivolts the casing and the pipe may still be adequately isolated. In this case the Corrosion Engineer shall submit a test approach and test data to verify isolation.

3. Acceptance: A potential difference of 30 millivolts or greater or the District's representative acceptance of the Corrosion Engineer's test report.

H. Potential Pipe-To-Soil Performance Summary

1. Responsibility: The Corrosion Engineer retained by the District shall conduct a pipe-to-soil potential survey after all test stations are installed.

2. Method: Native or initial pipe-to-soil potential shall be measured at all test stations and with all wires in each test station. All potentials shall be measured using a high impedance digital voltmeter and suitable leads with respect to a standard, recently-calibrated copper\copper sulfate reference electrode.

3. Report: The potential data shall be submitted in tabular form. The as-built location of each test reading shall be fully described.

4. Acceptance: A complete report and certification by the Corrosion Engineer that the test method was in accordance with industry standards and NACE RP0169.

I. Report

1. Verbal Report: All deficiencies found during testing or inspection shall be reported immediately to the District representative.

2. Written Report: The Corrosion Engineer retained by the District shall prepare a final report that contains the following:

   a. Verification that all test stations have been installed and installed properly.

   b. Verification that all insulating flanges have been tested with an approved test instrument and that all have passed.

   c. Field continuity test data, calculations of actual (measured) pipe resistance from the data and calculations of the theoretical resistance for each section of pipe tested. The report shall include a statement that each section of pipe that contains a bonded or mechanical joint was tested and that the resistance of each section tested was less than or equal to 130% of the theoretical resistance.

   d. Verification that all casings are isolated from the pipe.

   e. Tabulation of all pipe-to-soil potential survey data.

   f. Other information that the Corrosion Engineer believes is pertinent with respect to the corrosion status or long-term performance of the pipeline or structure installed.

J. Compliance With Specifications

1. 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: damaged wire; broken or missing test leads; improper or unclean wire trench backfill; lack of 18-inch slack wire in test boxes; improperly mounted or located test boxes; shorted insulators; discontinuous pipe; shorted casings; and other deficiencies associated with the workmanship, installation and non-functioning equipment.

END OF SECTION