PART 1    GENERAL

1.1 DESCRIPTION

A. Section includes requirements for installation of corrosion control system for pipelines.

1.2 QUALITY ASSURANCE

A. Materials:
   1. Follow applicable Standards for corrosion control.
   2. Supplied by manufacturer regularly engaged in production of corrosion control materials.

B. Installer: Install test stations, insulating joints, anodes, and joint bonding under supervision of corrosion control technician or corrosion engineer experienced in corrosion control work.

C. Corrosion Control Testing: Performed by NACE International Certified Corrosion Specialist, Senior Corrosion Technologist, or corrosion engineer with minimum 5 years experience in corrosion engineering.

1.3 SUBMITTALS

A. Submit following Section 01330.
   1. Catalog Data and/or Cuts.
      a. Materials for joint bonding, joint insulation, anodes and reference cells.
      b. Thermite weld packages, including manufacturer’s recommended cartridge and charge size for each application required.
      c. Test stations.
   2. Certification that magnesium anodes meet requirements of ASTM B843 and zinc anodes meet requirements of ASTM B418 and specifications noted herein.

B. Submit following Section 01450.
   1. Certificates:
      a. Installer and tester qualifications.
      b. Applicable NACE International Corrosion Certifications.
   2. Methods and procedures for testing corrosion control system, including description of instruments and equipment to be used.
      a. Test procedures for;
1) Verifying electrical isolation at insulating joints and insulating casing spacers.
2) Post installation testing of test stations and cathodic protection system.
3) Continuity testing (joint bond resistance).

3. List of minimum 5 projects that involve testing of corrosion control systems. Documentation for each project shall include:
   a. Project name.
   b. Project location (City and State).
   c. Pipe diameters and type of pipe material installed.
   d. Length of pipeline.
   e. Type of corrosion control provided on the pipeline.
   f. Name and phone number of a contact at the pipeline owner.
   g. Names of responsible corrosion control company staff members that participated in the project.

C. Submit all test results in a Final Acceptance Report for Contract Managers approval.
   1. Include sketches of test station wire terminations in each test box.
      a. Number each test station and identify type of station.

PART 2 PRODUCTS

2.1 MATERIALS

A. Wire
   1. Bonding Wire: Single conductor No. 2 or No. 4 AWG stranded copper rated at 600 volts with High Molecular Weight Polyethylene (HMWPE) black insulation. Wire size and length following Standard Detail C/1.0.
   2. Test Lead Wires: Single conductor No. 6 through No. 12 AWG stranded copper rated at 600 volts with THW, THHN, THWN or HMWPE insulation. Wire sizes and insulation colors following Standard Details and Drawings.
   3. Magnesium Anode Header Wire: Single conductor No. 8 AWG stranded copper wire rated at 600 volts with HMWPE black insulation for multiple galvanic anode installations, length as required.

B. Exothermic (Thermite) Weld Materials.
   1. Exothermic Weld Molds, Weld Powder and Weld Metal Cartridges: Use proper mold and proper size and amounts for wire size, pipe size, pipe material, and weld position. Utilize adapter sleeves as recommended by exothermic weld manufacturer.
   2. Approved Manufacturers:
      a. Exothermic weld material:
         1) ERICO International - CADWELD products
         2) Continental Industries - thermOweld products
         3) Or equal.
      b. Weld powder: As recommended by each exothermic weld manufacturer for specific wire size and pipe material.
c. Exothermic Weld caps:
   1) Continental Industries, Division of Burndy LLC – Ci theromOcap or Ci thermOcap PC weld caps.
   2) Royston Laboratories Division, Chase Corporation – Royston Handy Cap or Royston Handy Cap IP.
   3) Or equal.

d. Exothermic weld cap, pre-filled with mastic.
   1) Royston Handy Cap – use Royston Roybond 747 primer
   2) Royston Handy Cap IP – no primer needed (has integrated primer).
   3) Ci thermOcap – use thermOprimer primer.
   4) Ci thermOcapPC – no primer needed (pre primed cap)

e. Other exothermic weld caps: Field fill with mastic, following manufacturer’s instructions.

C. Terminals, Terminations and Connectors:
   1. Terminals for terminating test lead wires in test boxes: One piece, burr-free, crimp-type, non-insulated brazed seam terminals for 1/4 inch terminal studs, made of annealed electrolytic copper, sized to match various wire and stud sizes.
   2. Wire terminations for bolted connections: One piece bar lugs made of electrolytic grade copper bar stock and tin-plated, assembled or fabricated before field delivery.
      a. Approved Manufacturer.
         1) ERICO, Type LA.
         2) Or equal.
   3. Compression Connectors: One piece “C” shaped manufactured from high conductivity wrought copper for splicing copper cables together.
      a. Approved Manufacturer.
         1) Burndy, Type YC-C.
         2) Or equal.

D. Insulating Materials.
   1. Flange insulating kit.
      a. Flange Insulating Gasket: Full flange diameter, Type E, made of laminated phenolic with neoprene on each side of gasket with minimum total thickness of 1/8 inch.
         1) Dielectric strength: Not less than 500 volts per mil.
         2) Compressive strength: Not less than 24,000 psi.
         3) Water absorption: Maximum 2.5%.
         4) Approved manufacturers/suppliers:
            a) Advance Products & Systems, Inc.
            b) Central Plastics Company.
            c) Pipeline Seal and Insulator, Inc. (PSI).
            d) Or equal.
      b. Insulating Flange Bolt Sleeves: High density polyethylene or spiral wrapped Mylar with dielectric strength not less than 1,200 volts per mil.
c. Insulating Flange Bolt Washers: High strength phenolic with minimum thickness of 1/8 inch, dielectric strength not less than 500 volts per mil, and compressive strength not less than 25,000 psi.
d. Steel Flange Bolt Washers for placement over insulating washers: Minimum thickness of 1/8 inch and cadmium plated.
e. One Piece Combination Sleeve and Washer, only when noted on Drawings.
   1) One piece sleeve and washer of molded acetyl or nylon resin having minimum thickness of 1/8 inch.
      a) Dielectric strength not less than 500 volts per mil.
      b) Compressive strength not less than 15,000 psi.

2. Copper House Connections and Small Pipe Insulator.
   a. Copper house connection insulator: Two brass parts and nylon dielectric bushing.
   b. Insulator for other pipe 2 inch and smaller diameter: One piece threaded bushing made of nylon and sized to fit pipe.

E. Casing Spacers: See Section 02445.

F. Casing End Seals: See Section 02445.

G. Polyethylene Mesh Separator Pad.
   1. Medium density flexible polyethylene mesh pattern webbing pad, nominal thickness 160 mils.
      a. Approved Manufacturer.
         1) Stuart Steel Protection Corporation, Model Stuart Diamond Rockstop
         2) Or equal.

H. Electrical Tape
   1. Conformable water tight sealant having dielectric strength not less than 15kV for 1/8 inch thick layer.
      a. Approved Products.
         1) Scotch Vinyl Electrical Tape Super 88
         2) Scotch Linerless Rubber Splicing Tape 130C
         3) Or equal.

I. Test Stations: Flush mounted.
   1. Tube: Follow Standard Details.
   2. Cast iron or high impact plastic collar with ribs.
   3. Cast iron or high impact plastic locking lid, blue with permanent marking “WSSC Test Station” to withstand AASHTO H-20 traffic loads and ultra violet rays.
   4. Terminal Block: Phenolic resin, plastic, Micarta, Lexan, or Bakelite high dielectric material, with minimum of 7 terminals, unless otherwise shown on Drawings.
   5. Terminals: Nickel plated brass 1/4 inch threaded studs, nuts, and washers.
   6. Shunt: 0.01 ohm with minimum of 6 amperes capacity in test stations with galvanic anodes following Drawings.
J. Reference Electrodes
   1. Permanent copper-copper sulfate reference electrode.
      a. Designed for minimum 20 year life.
      b. Size: 2 inches diameter by 8 inches long, Schedule 80 PVC body or 2 inches
diameter by 7 inches long, high impact resistant Lexan tube and minimum
overall package size of 6 inches diameter by 10 inches long.
      c. Prepackaged in permeable cloth bag with special copper-copper sulfate
reference electrode backfill.
      d. Contents: High purity copper element, 99.99 percent pure, inside a tube
containing super saturated solution of copper sulfate.
      e. Lead wire:
         1) Sufficient length to reach test station terminals without splicing.
         2) AWG No. 12 or 14 stranded copper wire with HMWPE insulation.
         3) Wire insulation: Black.
         4) Attached to electrode core with manufacturer's standard connection.
            a) Connection shall be stronger than the wire.
         5) No splicing of electrode lead wire permitted under any circumstances.
      f. Approved Manufacturer.
         1) Electrochemical Devices, Inc., Model UL-CUG-SW
         2) Or equal.

K. Magnesium Anodes:
   1. Magnesium bar in prepackaged backfill with test lead wire.
   2. Nominal weight, excluding backfill: As shown on Drawings.
   3. Each anode: Vibratory packaged in water permeable cardboard box or water
permeable fabric sack, containing minimum of 40 pounds of backfill of the
following composition:
      a. Hydrated Gypsum 75%
      b. Bentonite 20%
      c. Sodium Sulfate 5%
   4. Lead Wire: No. 12 AWG 600 volts solid copper wire with THW, THWN, or
THHN white insulation, at least 15 feet long, and factory connected to galvanized
steel core with silver brazing alloy with minimum silver content of 15 percent.
   5. Chemical Composition of Magnesium Anodes: (percent by weight)

   Aluminum   0.01 Maximum
   Zinc        0.05 Maximum
   Manganese   0.50-1.30
   Copper      0.02 Maximum
   Silicon     0.05 Maximum
   Iron        0.03 Maximum
   Nickel      0.001 Maximum
   Others      0.050 each or 0.300 Maximum Total
   Magnesium   Balance
L. Zinc Anodes (for AC Ground Mats):
   1. Zinc ribbon: ASTM B418, Type II composition.
      a. 0.6 lbs/ft with cross section of 0.5 inch by 0.5625 inch.
      b. Continuously extruded over wire core of 0.13 inch diameter centrally located in the zinc alloy.

M. Detectable Warning Tape for Test Station Installations (Cathodic Protection): See Section 02315

PART 3 EXECUTION

3.1 THERMITE WELDING OF WIRES

A. Thermite weld test lead and joint bond wires to ductile iron and steel pipe joints and fittings, except where limited use of lugs is permitted following Standard Details.
   1. This weld process may be specified for use on other metallic structures.

B. Thermite welding equipment: Follow equipment manufacturer's instructions and Standard Details.
   1. Use equipment and molds to accommodate wire size, metallic structure's shape, wire position of attachment (vertical or horizontal) and other criteria specified.
   2. Before a mold is used, remove and clean slag, dirt, and other foreign matter from mold.
   3. Cartridge and charge size: Based on manufacturer's recommendations for specific application.
      a. Note: Different charges are required for steel and ductile iron.

C. Surface Preparation:
   1. Surfaces with little or no coating:
      a. Clean to bare metal by grinding or filing area approximately 3 inches square to produce bright metal surface.
      b. Remove coating, dirt, mill scale, oxide, grease, moisture, and other foreign matter from weld areas.
   2. Surfaces with high performance or thick coating: Cut 4 inch square window through coating and clean 3 inch square surface to bright metal, avoiding damage to surrounding coating.

D. Preparation for Welding.
   1. Before welding, remove wire insulation as required to fit mold, avoiding damage to exposed copper wire.
   2. If wire is cut or nicked over half way through its diameter, cut off and strip new end.
   3. If manufacturer requires use of copper sleeve, crimp it securely to wire and remove excess wire protruding from end of sleeve.

E. Test Connection.
1. After charge is set, remove mold and chip slag from weld area with welder's hammer.
2. Strike top and sides of weld with hammer to test bond of connection.
3. If weld does not hold, remove scrap weld material, clean, and begin weld process again.
4. After welding and before coating cleaned weld area, Engineer may test joint bond wires for electrical continuity.

F. Weld Caps.
1. After weld has passed tests for soundness and electrical continuity, clean thermite weld and area around it.
2. Apply pre-filled weld cap or field mastic-filled weld cap over thermite weld following manufacturer’s recommendations.
3. Coat remaining exposed pipe metal surface with petrolatum or petroleum wax mastic. Follow Field Applied Coating procedure in Section 02510.
4. Repair damage to pipe coating following coating manufacturer’s recommendations.
5. If weld cap will not fit due to physical space limitations, coat bare metal and wire in weld area with minimum 1/4 inch thickness of petrolatum or petroleum wax mastic. Place coating manufacturer’s mechanical protection film over field coated weld area, overlapping onto pipe coating, minimum of 6 inches. Follow Section 02510.

3.2 BOLTED WIRE CONNECTIONS

A. Bolted wire connections for bonding purposes are permitted to bolts on valve body following Standard Details and as specified herein.

B. Connect wire to bolt on valve body that is closest to pipe centerline.
   1. After valve bolt is removed, clean valve surface under bolt head to bright metal.

C. Use prefabricated bar lug on bonding wire end that will connect to valve bolt.
   1. Size bar lug hole to fit valve bolt, and make bolted connection following Standard Details.
   2. After bolted wire connection is completed, test joint bond wires for electrical continuity.
   3. After bond wire passes electrical continuity test, coat bar lug, exposed copper wire and exposed valve metal with minimum 1/4 inch of petrolatum or petroleum wax mastic.

3.3 JOINT BONDING OF PIPE

A. Bond pipe joints and fittings to form electrically continuous pipeline following Drawings and Standard Details.

B. Wire.
1. Joint bonding wire: Sized according to pipe diameter and following Standard Details.
2. Cut bond wire to shortest length practicable, including some slack, for given span.
   a. Locate bond wire welds on pipe and fittings following Standard Details.
   b. Horizontal welds are preferable, but where there is insufficient space on a fitting, vertical welds will be permitted.
   c. Where multiple parallel bond wires are involved, space wires neatly and without wires crossing each other.
3. Do not splice bond wires.
   a. Replace bond wires broken during construction.
   b. Reweld loose weld connections.
4. If insulation of bond wire is damaged between welds, repair insulation:
   a. Thoroughly clean damaged area and 6 inches either side of it.
   b. Wrap minimum of one overlapping layer of rubberized electrical tape around damaged area and extend at least 2 inches each side.
   c. Wrap two overlapping layers of plastic electrical tape around rubberized tape and extend at least 1 inch beyond rubberized tape at each end.

3.4 ANODE INSTALLATION

A. Prepackaged magnesium and zinc anodes: Installed where indicated on Drawings.
   1. Before installation, remove all shipping covers from anode (the prepackaged cotton bag or cardboard box for magnesium and zinc anodes shall not be removed).
   2. Do not lift anode by lead wire.
   3. Protect cloth sack or cardboard box with prepackaged backfill surrounding anode from tearing or damage.
      a. If damage occurs, provide new prepackaged anode.
   4. Install anodes in existing soils (free from rocks, roots, organic material, trash or other debris) and backfill with minimum of 6 inches of existing soil.
      a. Do not install anode in sand, rock or gravel backfill.
   5. Provide minimum anode spacing of two feet from other pipelines.
   6. Pre-soak anode with 5 gallons of water after placement, but before backfilling, unless groundwater covers it.

B. Anode Lead wires.
   1. At test stations with anodes;
      a. Install anode lead wires minimum two feet below grade. Handle wire with care.
      b. Connect anode lead wire to terminal block at test station, as shown on Drawings and Details, using proper sized crimp type connectors on wire ends.
   2. Anodes on header cables;
      a. Connect anode lead wires to header cable as shown on Drawings and Details, using the specified connectors and splice protection.
b. Connect anode header cable to terminal block at test station, as shown on Drawings using proper sized crimp type connectors on wire ends.

3.5 INSTALLATION OF TEST STATIONS

A. Location of Test Stations:
   1. Follow Drawings and Standard Details.
      a. Locate surface of concrete pad at finish grade, unless otherwise directed by Engineer.
      b. Locate directly over pipeline except in areas that would place the test station in a roadway.
         1) Locate these test stations to closest point just off the edge of the road or curb.
   2. Identify test station with number following Drawings or Engineer furnished number.
      a. Paint number legibly inside test box lid or cover and on terminal block.
      b. Use permanent and weatherproof paint for metal or plastic surfaces.
   3. Immediately after installation in areas to be improved, protect and identify test station locations with 3 stakes extending at least 4 feet above existing grade, equally spaced around test station and wrapped with orange fluorescent flagging material within 6 inches from top of stakes.
   4. Situate pipe for pipe mounted test stations directly over pipeline.
      a. If this is not possible, locate at Engineer’s direction.

B. Test Lead Wires:
   1. Install test lead wires without splices as shown on Standard Details and attach to pipe using exothermic welding method.
   2. Locate wires on top and along pipe and at right angles to pipeline when wires depart for offset test stations.
      a. Test station wires: Routed minimum of two feet below finished grade.
      b. Test lead wires: Routed under roadway to the test station through conduit, as necessary.
      c. Protect wires from damage during backfilling operations with adequate slack and support.
   3. Place continuous yellow detectable warning tape directly over test lead wires, 12 inches to 18 inches below finished grade.
   4. Terminate test lead wires inside test box using proper sized crimp type connectors on wire ends.
      a. Connect each wire to terminal, maintaining at least 18 inches slack in each wire at test station. Do not combine wires on a terminal except as necessary for anode connections.
      b. Neatly coil slack wire in test station below terminal board.
   5. Test each lead wire for continuity after backfill is completed.
      a. If test for continuity fails, repair or replace at Engineer’s direction.

C. Reference Cells: Follow Standard Details or Drawings.
1. Use native trench material to backfill the reference electrode.
2. Before installation, remove the plastic shipping cover from the reference electrode.
3. Cloth bag containing the special backfill shall remain intact.
4. Protect cloth bag from tearing or damage.
5. If damage occurs, provide new prepackaged reference cell.
6. Test wire from reference cell for proper function.
   a. If reference cell is not functioning properly, repair or replace.
   b. After reference cell is functioning properly, connect lead wire from reference cell to terminal block at test station.
   c. Do not attach other test lead wires to terminal that is used for reference cell.

D. IR Drop Lead Wires:
   1. Locate IR drop test stations following Drawings.
   2. Wire size, type, and length: Following Standard Details.
   3. Place long lead wires below springline of pipe and taped to pipe for protection, following Drawings.

E. Shunts:
   1. Install shunts and/or copper shorting straps in test stations with anodes following Drawings.

F. Foreign Pipeline:
   1. Provide test stations at foreign pipelines following Drawings and Standard Details.

G. Notify owner of foreign pipeline at least 2 weeks before test station construction. Unless otherwise indicated, only foreign pipeline owner or approved representative will be permitted to weld wires to foreign pipeline.

3.6 CLEARANCE TO OTHER STRUCTURES

A. Maintain one foot clearance to other structures, where possible.
   1. When one foot can not be maintained, install flexible polyethylene mesh webbing pad around the new piping and secure with non-metallic tape.

3.7 INSULATING JOINTS

A. Install following Standard Details and Drawings.

B. Test each insulator for electrical insulation before backfilling. Provide Engineer a minimum of one week notice prior to testing.
   1. If insulator is not properly isolated, repair or replace all defective components at no additional cost to the Commission.
   2. Test the repaired insulator.
   3. Continue this process until the insulator is tested to be properly isolated.

System Extension Permit

SP-13110-10

July 2013
4. Insulation that passes for effective isolation during the pre-backfill test, but does not render positive isolation results during acceptance testing shall be repaired.

C. Coat entire joint including bolt ends and nuts with coating material specified herein. Fully coat minimum of 12 inches on each side of flange.
   1. Clean surface of flange and components and prepare surface following manufacturer’s recommendations.
   2. Apply uniform coat of primer to flange and all components.
   3. Apply filler mastic to all irregular surfaces of flange to provide smooth profile for tape application.
   4. Apply innerwrap to flange and all components in spiral fashion; minimum overlap 55 percent.
   5. Apply outerwrap to flange and all components in spiral fashion; minimum overlap 1 inch with sufficient tension to provide continuous adhesion of tape.

D. For copper house connections and other small pipe, install connection insulator following Drawings.
   1. Locate insulator at copper pipe tie-in following Standard Details.

3.8 CONCRETE BUTTRESSES, SUPPORT BLOCKS, ANCHOR BLOCKS, AND OTHER CONCRETE STRUCTURES

A. Position reinforcing steel used in construction of support blocks, anchor blocks, and other concrete structures so it is not in contact with piping.
   1. Maintain minimum of 2 inch clearance between piping and reinforcement steel or other metallic components.
   2. Under no circumstances shall metallic pipe be in contact with reinforcing steel.

3.9 INSULATED CASING SPACERS AND CASING END SEALS

A. Each length of pipe within casing: Supported and electrically isolated from casing by the use of insulating spacers (supports).
   1. Number of casing spacers and spacing between them: Following recommendations of casing spacer manufacturer.
      a. Minimum of three (one at each end and one at the midpoint of the pipe) is required to support each section of pipe.
   2. Insulating spacers: Sufficient dimension to center carrier pipe within the casing and to serve as runners to slide carrier through the casing.

B. After carrier pipe is installed within the casing, test electrical isolation between the casing and carrier pipe. Provide minimum one week notice prior to completion of the installation of piping within casing.
   1. If carrier pipe is not electrically isolated from the casing, remove carrier pipe from the casing, replace any and all defective or damaged casing spacers and reinstall carrier pipe in the casing.
   2. Retest the repaired electrical isolation.
3. Continue this process until the casing is tested to be electrically isolated from carrier pipe.

4. Repair pipe to casing insulation that passes for effective isolation during the pre-backfill test, but does not render positive isolation results during acceptance testing.

C. After casing isolation has been confirmed as effective, install casing end seals at both ends of casing.

1. Casing end seals: Installed following written instructions of end seal manufacturer.

3.10 PLACING SYSTEM IN SERVICE

A. Accomplish final connections and place Cathodic Protection System in service as specified under Post Installation Corrosion Control Testing.

3.11 POST INSTALLATION CORROSION CONTROL TESTING

A. Acceptance criteria for effective cathodic protection: Following NACE International SP0169, “Control of External Corrosion on Underground or Submerged Metallic Piping Systems”. Use one or a combination of the following:

1. Negative voltage of at least 0.85 volt with cathodic protection applied.
   a. This potential is measured with respect to a saturated copper-copper sulfate reference electrode contacting the electrolyte, using both permanently installed and portable reference electrodes.
   b. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement, or

2. Negative polarized potential of at least 0.85 volt relative to a saturated copper-copper sulfate reference electrode, or

3. A minimum of 100 mV of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The formation or decay of polarization can be measured to satisfy this criterion.

B. All testing: Witnessed by Engineer. Provide Engineer minimum of one week notice prior to conducting any testing.

C. Record methods and instruments used to perform required tests including all readings, measurements, and calculated resistances.

D. Minimum Equipment to Perform Corrosion Control Testing:

1. DC ammeter with full scale ranges of 1, 10, and 100 amperes, accurate to within 1 percent of full scale. A millivolt meter with 1 percent of full scale accuracy and shunts may also be used.

2. Voltmeter with minimum input resistance of 10 megohms, with DC low range of 200 millivolts full scale to DC high range of 100 volts full scale and accurate to within 1 percent of full scale.
3. Alternative to 1. and 2. above, may be high impedance multi combination voltmeter-ammeter used with 100 ampere shunt, Miller B-3D, B3-A2, M-3-A2, or equal.
4. DC power supply with steady capacity of 50 amperes minimum, produced from portable cathodic protection rectifier, 6 or 12 volt automotive type wet cell batteries, or equal.
5. Test leads and clamps suitable for carrying test current, rated up to 75 amperes with lead wire length.
6. Multiple wire reels with appropriately gauged wire for carrying out the required tests.
7. Adjustable resistors with sizes and capacities to handle desired outputs.
8. Safety switch rated for test current.
9. One pair of electrical probes for voltmeter.
10. Saturated copper-copper sulfate reference cell(s).
12. For close interval pipe-to-soil potential surveys, utilize the following:
   a. American Innovations Allegro Data Logger, or approved substitution.
   b. Footage chainer/counter.

E. Continuity Testing:
1. Submit records of joint bond resistance testing including:
   a. Instruments and equipment used, with sketch of test connections.
   b. Test amperages, voltages, and voltage changes during testing.
   c. Joint resistance, measured and calculated.
   d. Location of each test station, giving pipe station and street address, and GPS coordinates.
2. Measure joint bond resistances:
   a. Conduct longitudinal pipe resistance measurements between consecutive test stations.
      1) Measured by impressing a DC test current between pipe test lead wires at consecutive test stations.
      2) Simultaneously measure DC voltage between pipe test lead wires at the same consecutive test stations while impressing the DC current.
   b. Calculate the resulting span resistance and submit to Engineer for review and acceptance.
      1) Submit all calculations and data in their entirety.
      2) Provide GPS coordinates for each test station.
3. Calculate theoretical joint and bond resistances:
   a. Measure distance between test stations.
   b. Using Calculated Resistance Table herein at end of Section, multiply measured distance by Resistance per Foot (ohms) from table to obtain theoretical (or calculated) resistance of pipe and multiply number of bonded pipe joints by the theoretical resistance of a joint bond.
   c. Acceptable resistance: Measured resistance shall not exceed 15 percent of calculated resistance.
F. Insulator Testing (Insulated Flanges, and Insulated Casing Spacers):
1. After assembly and prior to backfilling, test each insulating joint for insulation using methods generally accepted in corrosion control engineering.
   a. Repair or replace defective or ineffective insulating joint.
2. Submit records of insulated joint testing including:
   a. Test method and instruments used, with sketch of test connections.
   b. Location of insulated joint, giving pipe station and street address, and GPS coordinates.
   c. Instrument readings of current, voltage, and calculated resistance.
3. Acceptance criteria:
   a. High frequency isolation tester: "Acceptable", "Satisfactory" or other similar direct meter reading, and
   b. Electrical potential/applied current: Static potential difference across insulator of no less than 0.1 volt before application of test current; a positive potential shift on the side of the insulator where current is applied, and a negative potential shift on the side of the insulator opposite of where current is applied.

G. Test Station Lead Wire Testing:
1. Test each wire with a high impedance (minimum 10 megohms) DC voltmeter and copper-copper sulfate reference electrode. Testing shall include the permanent reference electrodes, anodes, and all pipe test lead wires. Testing shall be conducted before anode header cable is connected to the shunt terminal.
2. Acceptance criteria:
   a. Ductile iron will be between 0.50 to 0.65 volt to a copper-copper sulfate (Cu/CuSO₄) reference electrode.
   b. Zinc anodes will be between 1.00 and 1.10 volts to Cu/CuSO₄.
   c. The permanent copper-copper sulfate reference electrode will be between -0.05 and +0.05 volt to a portable copper-copper sulfate.
   d. Record all data (with GPS coordinates) and include in the final acceptance test report.

H. After Backfill is Completed and Test Stations are in Place:
1. Test and verify continuity and electrical isolation of pipeline.
2. Measure pipe-to-soil potentials in close interval over-the-line survey, continuously at electrode spacing not to exceed 2.5 feet.
3. Relate contact points of reference electrodes to pipeline stations and known pipeline appurtenances, including test stations.
4. Prepare as-built sketch of each test station terminal board and test lead wire hookups.
5. Provide plan view sketch of each test station location with physical features and GPS coordinates as follows: Horizontal Control--MD State Plane Coordinates NAD83/91 to 0.01 foot accuracy, Vertical Control--NGVD29 to 0.01 foot accuracy.
6. Submit as-built sketches in hard copy and electronically in AutoCAD format.
I. Corrosion Control Testing Sequence.

1. Before anode connection:
   a. Close interval pipe-to-soil potential survey (see below).
   b. Pipe-to-soil potential at each test station.
   c. Reference cell-to-pipe potential at each test station.
   d. IR drop calculations (K factor).
   e. IR drop measurements - current flow and direction.
   f. Anode potential.

2. At time of anode connection:
   a. Connect anodes to an appropriate test lead wire and shunt in each test station.
   b. Pipe-to-soil potential at each test station.
   c. Reference-to-pipe potential at each test station.
   d. IR drop measurements - current flow and direction.
   e. Anode current output.

3. Three to 4 weeks following anode connection (i.e., cathodic protection system activation):
   a. Close interval pipe-to-soil potential survey (see below).
   b. Pipe-to-soil potential at each test station.
   c. Reference cell-to-pipe potential at each test station.
   d. IR drop measurements - current flow and direction.
   e. Anode current output.

4. Close Interval Pipe-to-Soil Potential Surveys
   a. As noted above, over-the-line “on” and “off” close interval potential surveys with 2.5 foot spacing shall be performed.
      1) Close interval survey data shall be submitted in graphic and tabular format.
      2) Graphs shall show no more than 500 feet of pipe per 8.5 inch by 11 inch page and features shall be provided on the graphs and tables for identifying data points.
      3) Only computer generated graphs and tables shall be acceptable.
      4) This testing shall be performed with the following equipment:
         a) American Innovations’ Allegro Data Logger with companion software, or approved equal.
         b) Copper-copper sulfate reference cell(s).
         c) Footage chainer/counter.

J. Final Acceptance Test Report:

1. Include all final test data tabulated in computer generated format.
   a. Description of all test procedures.
   b. Legible sketches with GPS coordinates of test station locations.
   c. Test station as-built tie-down sketches in AutoCAD format.
   d. Conclusions as to the condition and the operating status and effectiveness of the cathodic protection system.

2. Provide certification that cathodic protection system is functioning following NACE SP0169.
a. Contractor's NACE certified corrosion control engineer or technician shall sign the Final Acceptance Test Report and include his/her NACE certificate number with his/her signature.

3.12 Defective or Improperly Installed Components.

A. The repair or replacement of any defective or improperly installed component of the cathodic protection system or corrosion monitoring facility shall be the sole responsibility of the Contractor. Any and all repairs or replacement of defective or improperly installed corrosion control components shall be performed by the Contractor.
<table>
<thead>
<tr>
<th>Diameter in Inches</th>
<th>Class</th>
<th>Resistance Per Foot (OHM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>51</td>
<td>0.0000762</td>
</tr>
<tr>
<td>4</td>
<td>52</td>
<td>0.0000688</td>
</tr>
<tr>
<td>4</td>
<td>53</td>
<td>0.0000628</td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td>0.0000578</td>
</tr>
<tr>
<td>4</td>
<td>55</td>
<td>0.0000536</td>
</tr>
<tr>
<td>4</td>
<td>56</td>
<td>0.0000500</td>
</tr>
<tr>
<td>6</td>
<td>51</td>
<td>0.0000486</td>
</tr>
<tr>
<td>6</td>
<td>52</td>
<td>0.0000441</td>
</tr>
<tr>
<td>6</td>
<td>53</td>
<td>0.0000404</td>
</tr>
<tr>
<td>6</td>
<td>54</td>
<td>0.0000373</td>
</tr>
<tr>
<td>6</td>
<td>55</td>
<td>0.0000346</td>
</tr>
<tr>
<td>6</td>
<td>56</td>
<td>0.0000323</td>
</tr>
<tr>
<td>8</td>
<td>50</td>
<td>0.0000380</td>
</tr>
<tr>
<td>8</td>
<td>51</td>
<td>0.0000343</td>
</tr>
<tr>
<td>8</td>
<td>52</td>
<td>0.0000313</td>
</tr>
<tr>
<td>8</td>
<td>53</td>
<td>0.0000288</td>
</tr>
<tr>
<td>8</td>
<td>54</td>
<td>0.0000266</td>
</tr>
<tr>
<td>8</td>
<td>55</td>
<td>0.0000248</td>
</tr>
<tr>
<td>8</td>
<td>56</td>
<td>0.0000233</td>
</tr>
<tr>
<td>10</td>
<td>50</td>
<td>0.0000287</td>
</tr>
<tr>
<td>10</td>
<td>51</td>
<td>0.0000261</td>
</tr>
<tr>
<td>10</td>
<td>52</td>
<td>0.0000239</td>
</tr>
<tr>
<td>10</td>
<td>53</td>
<td>0.0000221</td>
</tr>
<tr>
<td>10</td>
<td>54</td>
<td>0.0000205</td>
</tr>
<tr>
<td>10</td>
<td>55</td>
<td>0.0000192</td>
</tr>
<tr>
<td>10</td>
<td>56</td>
<td>0.0000180</td>
</tr>
<tr>
<td>12</td>
<td>50</td>
<td>0.0000225</td>
</tr>
<tr>
<td>12</td>
<td>51</td>
<td>0.0000206</td>
</tr>
<tr>
<td>12</td>
<td>52</td>
<td>0.0000190</td>
</tr>
<tr>
<td>12</td>
<td>53</td>
<td>0.0000176</td>
</tr>
<tr>
<td>12</td>
<td>54</td>
<td>0.0000164</td>
</tr>
<tr>
<td>12</td>
<td>55</td>
<td>0.0000154</td>
</tr>
<tr>
<td>12</td>
<td>56</td>
<td>0.0000145</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
<td>0.0000182</td>
</tr>
<tr>
<td>14</td>
<td>51</td>
<td>0.0000167</td>
</tr>
<tr>
<td>Diameter in Inches</td>
<td>Class</td>
<td>Resistance Per Foot (OHM)</td>
</tr>
<tr>
<td>-------------------</td>
<td>-------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>14</td>
<td>52</td>
<td>0.0000155</td>
</tr>
<tr>
<td>14</td>
<td>53</td>
<td>0.0000144</td>
</tr>
<tr>
<td>14</td>
<td>54</td>
<td>0.0000135</td>
</tr>
<tr>
<td>14</td>
<td>55</td>
<td>0.0000127</td>
</tr>
<tr>
<td>14</td>
<td>56</td>
<td>0.0000119</td>
</tr>
<tr>
<td>16</td>
<td>50</td>
<td>0.0000155</td>
</tr>
<tr>
<td>16</td>
<td>51</td>
<td>0.0000143</td>
</tr>
<tr>
<td>16</td>
<td>52</td>
<td>0.0000132</td>
</tr>
<tr>
<td>16</td>
<td>53</td>
<td>0.0000123</td>
</tr>
<tr>
<td>16</td>
<td>54</td>
<td>0.0000115</td>
</tr>
<tr>
<td>16</td>
<td>55</td>
<td>0.0000109</td>
</tr>
<tr>
<td>16</td>
<td>56</td>
<td>0.0000103</td>
</tr>
<tr>
<td>20</td>
<td>50</td>
<td>0.0000118</td>
</tr>
<tr>
<td>20</td>
<td>51</td>
<td>0.0000109</td>
</tr>
<tr>
<td>20</td>
<td>52</td>
<td>0.0000101</td>
</tr>
<tr>
<td>20</td>
<td>53</td>
<td>0.0000095</td>
</tr>
<tr>
<td>20</td>
<td>54</td>
<td>0.0000089</td>
</tr>
<tr>
<td>20</td>
<td>55</td>
<td>0.0000084</td>
</tr>
<tr>
<td>20</td>
<td>56</td>
<td>0.0000079</td>
</tr>
<tr>
<td>24</td>
<td>50</td>
<td>0.0000093</td>
</tr>
<tr>
<td>24</td>
<td>51</td>
<td>0.0000087</td>
</tr>
<tr>
<td>24</td>
<td>52</td>
<td>0.0000081</td>
</tr>
<tr>
<td>24</td>
<td>53</td>
<td>0.0000076</td>
</tr>
<tr>
<td>24</td>
<td>54</td>
<td>0.0000071</td>
</tr>
<tr>
<td>24</td>
<td>55</td>
<td>0.0000067</td>
</tr>
<tr>
<td>24</td>
<td>56</td>
<td>0.0000064</td>
</tr>
<tr>
<td>30</td>
<td>50</td>
<td>0.0000073</td>
</tr>
<tr>
<td>30</td>
<td>51</td>
<td>0.0000066</td>
</tr>
<tr>
<td>30</td>
<td>52</td>
<td>0.0000061</td>
</tr>
<tr>
<td>30</td>
<td>53</td>
<td>0.0000056</td>
</tr>
<tr>
<td>30</td>
<td>54</td>
<td>0.0000052</td>
</tr>
<tr>
<td>30</td>
<td>55</td>
<td>0.0000049</td>
</tr>
<tr>
<td>30</td>
<td>56</td>
<td>0.0000046</td>
</tr>
<tr>
<td>36</td>
<td>50</td>
<td>0.0000055</td>
</tr>
<tr>
<td>36</td>
<td>51</td>
<td>0.0000050</td>
</tr>
<tr>
<td>36</td>
<td>52</td>
<td>0.0000045</td>
</tr>
<tr>
<td>36</td>
<td>53</td>
<td>0.0000041</td>
</tr>
</tbody>
</table>
CALCULATED RESISTANCE TABLE

**DUCTILE IRON PIPE**

<table>
<thead>
<tr>
<th>Diameter in Inches</th>
<th>Class</th>
<th>Resistance Per Foot (OHM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>54</td>
<td>0.0000038</td>
</tr>
<tr>
<td>36</td>
<td>55</td>
<td>0.0000035</td>
</tr>
<tr>
<td>36</td>
<td>56</td>
<td>0.0000033</td>
</tr>
<tr>
<td>42</td>
<td>50</td>
<td>0.0000043</td>
</tr>
<tr>
<td>42</td>
<td>51</td>
<td>0.0000039</td>
</tr>
<tr>
<td>42</td>
<td>52</td>
<td>0.0000035</td>
</tr>
<tr>
<td>42</td>
<td>53</td>
<td>0.0000032</td>
</tr>
<tr>
<td>42</td>
<td>54</td>
<td>0.0000029</td>
</tr>
<tr>
<td>42</td>
<td>55</td>
<td>0.0000027</td>
</tr>
<tr>
<td>42</td>
<td>56</td>
<td>0.0000025</td>
</tr>
<tr>
<td>48</td>
<td>50</td>
<td>0.0000035</td>
</tr>
<tr>
<td>48</td>
<td>51</td>
<td>0.0000031</td>
</tr>
<tr>
<td>48</td>
<td>52</td>
<td>0.0000028</td>
</tr>
<tr>
<td>48</td>
<td>53</td>
<td>0.0000025</td>
</tr>
<tr>
<td>48</td>
<td>54</td>
<td>0.0000023</td>
</tr>
<tr>
<td>48</td>
<td>55</td>
<td>0.0000021</td>
</tr>
<tr>
<td>48</td>
<td>56</td>
<td>0.0000019</td>
</tr>
<tr>
<td>54</td>
<td>50</td>
<td>0.0000028</td>
</tr>
<tr>
<td>54</td>
<td>51</td>
<td>0.0000025</td>
</tr>
<tr>
<td>54</td>
<td>52</td>
<td>0.0000022</td>
</tr>
<tr>
<td>54</td>
<td>53</td>
<td>0.0000020</td>
</tr>
<tr>
<td>54</td>
<td>54</td>
<td>0.0000018</td>
</tr>
<tr>
<td>54</td>
<td>55</td>
<td>0.0000017</td>
</tr>
<tr>
<td>54</td>
<td>56</td>
<td>0.0000015</td>
</tr>
</tbody>
</table>

Joint Bond Wire Resistances

- **#2AWG Wire** 0.000162 OHM Per Foot
- **#4AWG Wire** 0.000259 OHM Per Foot

**WSSC**