# I. Corrosion Control

All storage tanks, pumping stations, vaults, treatment equipment, and similar facilities shall be protected from corrosion using project-specific design guidelines, which are not included within this discussion. All steel tanks shall have a corrosion consultant designed impressed current system. The following guidelines are to be applied to all underground water, reclaimed water, and pressurized wastewater pipelines that are to be made of metallic pipe.

In certain cases, upon completion of the decision process described below, Loudoun Water may choose to specify a nonmetallic piping material in an application that would otherwise be built of ductile iron.

# II. Design

### A. Summary

This summary outlines how Loudoun Water will determine and implement corrosion control method decisions for buried metallic pipelines. The decision process considers criteria including: pipeline's size, function, accessibility, cost of repair; anticipated corrosiveness of soil; and the potential for stray currents that may affect the pipelines. Based on an evaluation of these criteria, Loudoun Water will determine the level of corrosion protection to be applied to the pipeline. Three levels of protection are considered for every pipeline and include the following:

1. specific corrosion control design (such as joint bonding, test stations, and cathodic protection) and appropriate electrical isolations,
2. enhanced protection with V-Bio polyethylene encasement. No test stations or joint bonding,
3. conventional polyethene encasement with mechanical joint coating, but no test stations or joint bonding, and
4. standard installation with mechanical joint coating and no test stations or joint bonding.

The decision process is described in the following sections and summarized in **Figure E.1**. The decision process consists of four steps:

Step 1: classify each pipeline

Step 2: evaluate the anticipated soil conditions for each pipeline

Step 3: identify stray currents

Step 4: determine the level of corrosion protection to be applied to each pipeline and incorporate into the construction plans and specifications

## B. Decision Process

**Step 1: Pipeline Classification** Proposed pipelines shall be designated one of three classifications (Class 1, 2, or 3). Classifications are primarily based on size, function, and accessibility of the pipeline, the consequence of failure. Loudoun Water reserves the right to adjust the classification of individual pipelines at its own discretion.

**Class 0** pipelines represent the highest priority classification. These are metallic pipelines that are 30” diameter and larger.

**Class 1** pipelines meet any of the following criteria:

- metallic sewer force mains 6” diameter and larger; metallic water mains 16 inches in diameter and larger,
- or a 12” diameter metallic water main that is a single feed, or has a high consequence of failure.

**Class 2** pipelines meet any of the following criteria:

- Metallic water mains 12 inches in diameter;
- smaller than 12” diameter metallic water mains providing a single feed to distribution systems where a failure would result in significant disruption to customer service (approximately 40 or more service connections);
- any metallic pipeline where repair or taking the line out of service would require exceptionally high repair costs, difficult repair conditions, or long-term customer service disruption, that doesn’t meet the class 1 or class 0 requirements.

**Class 3** pipelines are:

- metallic water mains less than 12 inches in diameter that don’t meet any of the above requirements.

**Step 2 – Soil Evaluation Guidelines**

Soil characteristics surrounding the pipeline trench significantly affect the rate of metallic pipeline corrosion. Where ductile iron lines are to be constructed, soil samples shall be collected and analyzed as described herein. Proposed soil boring locations shall be submitted at the time of the first submission of plans. The results of the analysis shall be submitted to Loudoun Water by the Engineer at the time of the second submission of construction plans. Construction plans will not be approved by Loudoun Water until soil results have been submitted and appropriate corrosion protection measures incorporated into the design. Guidelines for soil sample collection and analysis follow.

When existing water conveyance piping is assessed for replacement or a new main is designed, the alignment of a given section or segment should be surveilled from the surface to identify conditions that have the propensity to create corrosive soils.

**Surveillance Guidance for Soil Sampling for Corrosivity Testing**

1. Locations of frequent prior water main leaks with no other known factors.

2. Proximity of water main alignments to wetlands, marsh areas, or water courses.

3. Proximity of water main alignments to run-off areas for deicing salts in roadways. Larger roadways and downhill sides of roadways or parking areas to be identified.

4. Proximity of water main alignments to high pressure steel gas mains or oil pipelines protected by Impressed Current Cathodic Protection Systems.

5. Proximity of water main alignments to large electrical substations or beneath overhead high voltage power lines.

6. Proximity of water main alignments to known rocky soil conditions.

7. Proximity of water main alignments to old industrial sites such as power plants, factories, mills, chemical plants, coal gas plants, landfills, or dump sites.

8. Locations where multiple types of different metals are in close contact.

For all Class 0, 1 and 2 pipelines, Loudoun Water will require additional soil investigations, to include in situ soil resistivity, sulfides, sulphates, and pH. These tests must be conducted, and reports prepared under the supervision of an engineer who is certified by the National Association of Corrosion Engineers (NACE).

1. Collection of Soil Samples

   a. Soil samples may be collected by the geotechnical engineering firm performing geotechnical investigations for development activities as required by the Loudoun County Facility Standards Manual. Loudoun Water reserves the right to require the Engineer to collect additional samples other than those detailed herein. Further, Loudoun Water may require additional soil investigations for corrosion considerations.

   Geotech reports should provide the following information:

- provide the elevation of normal ground water and seasonal high ground water depth,
- identify the USCS soil type, strata, and depth,
- provide the pH of the soil,
- provide the level or presence of sulfides and sulphates,
- resistivity, and
- identify if organics, especially decaying plant life, are present.

b. Loudoun Water will direct the collection of additional soil samples of fill transported from offsite locations used for controlled backfill, in the backfill of rock trenches, or other fill conditions.

c. Soil samples shall be collected as follows:

i) The depths of soil samples collected for corrosion evaluation shall be representative of anticipated pipeline depths. If pipeline locations and depths are not known, the samples shall be collected at a depth approximately 4.0 feet below existing grade, or the deepest location where soil is available for testing (if rock is encountered before 4.0 feet).

ii) Soil samples shall be collected from each soil boring performed as part of site plan geotechnical investigations. The number and location of soil borings shall be consistent with the site plan geotechnical guidelines specified by the Loudoun County Facility Standards Manual.

iii) Soil samples for all pipelines evaluated by geotechnical investigations shall be taken at intervals of 1,000 linear feet along proposed pipeline alignments.

iv) The coordinates and elevation where the sample was obtained shall be recorded and provided to Loudoun Water, including horizontal and vertical datum of the coordinate system used.

2. Analysis of Soil Samples

a. All soil samples shall be tested for pH, sulfate concentration, sulfide content and resistivity (as received and saturated). Data for each sample shall be recorded on the data sheet form that accompanied the soil sample.

b. The test methods to be used for laboratory analysis shall comply with the following ASTM standards.

i) Sample Preparation (ASTM D1193)

ii) Sulfate Content (ASTM Standard Test Method D516)

iii) Resistivity (ASTM Standard Test Method G57)

iv) pH (ASTM Standard Test Method G51)

v) Sulfide test per sodium azide-iodine qualitative tests per AWWA C105

**<u>Soil Corrosivity Parameter Testing Guidelines</u>**

Soil Corrosivity Testing - Soil Samples shall be tested for the corrosivity parameters listed below:

Soil samples shall be collected via borings or geo-probes along the water main alignment. Where stratified soils are present, multiple samples shall be taken. If homogenous soils are present in removed borings, only one sample shall be obtained at each location. Soil samples shall be tested for the following parameters:

- Kind of Soil – i.e. gravel, sand, clay, etc.

- Soil Condition – i.e. ground water presence, disturbed, undisturbed, stratified at pipe depths or uniform, etc.
- Specific Soil Resistance (Resistivity).
- Water Content.
- pH Value.
- Redox Potential.
- Presence of Sulfides.
- Sulfate Concentration.

Borings are to be obtained within 10-feet of the water main location horizontally and samples to be obtained from mid to bottom buried depths of pipe. These parameters have a ranking number system that is tied to Soil Aggressivity. Please see Figure 1 below to determine the class of the soil for corrosion protection requirements.

**SOIL PARAMETERS/METHODS OF ANALYSES**

1. *Kind of Soil:* Determined using the Particle Size Analysis following the standards for the Unified Soil Classification System (USCS).
2. *Specific Soil Resistance:* Measured using a Nilsson Model 400 Soil Resistance Meter and an AGRA Mark I Soil Box. Soil resistance is measured in the as-received condition and water saturated condition.
3. *Water Content:* Approximately 5 grams of a soil sample was dried for 24 hours at 105 C, and the loss of water (mass) was calculated a percentage of the dried soil mass.
4. *pH:* Using Water pH technique described in Methods of Soil Analysis, Cooperative Bulletin #10 published by the University of Delaware. In this technique, the pH of a 1:1 soil (air-dried, 2 mm sieved): deionized water slurry is measured.
5. *Redox Potential:* Measured directly on the as-received soil using platinum versus Ag/AgCl reference electrode.
6. *Hydrogen Sulfide or other sulfide:* Determined qualitatively using the Azide method described in ANSI/AWWA C105/A21.5-88.
7. *Sulfate Content:* Measured by ion chromatography (IC) on a portion of a 5:1 soil: deionized water extract and calculated back to the soil on a weight basis.
8. *Soil condition and the presence of coal or coke must be determined onsite.*

Pick the soil that is the depth that the pipe will be located. Determine the scores for each of the below categories and sum.
Class A Soil: Score of -10 or less Class B Soil: Everything Else

If pipe is installed in a landfill, within cinders, mine waste, fly ash or coal, automatically assume Class A soil.

If the pipe trench will be in rock, use backfill soil characteristics to determine soil class

| Soil Type | |
|---|---|
| Sand/Gravel (GW, GP, GM, GC, SW, SP, SM, SC) | +2 |
| Silt (ML, MH) | +0 |
| Clay (CL, OH, CH, OL, OH) | -2 |
| Peat/Bog (Pt) | -4 |

| Resistivity | |
|---|---|
| Greater Than 10,000 Ohms | 0 |
| 10,000 - 5,000 Ohms | -1 |
| 4,999 - 2,300 Ohms | -2 |
| 2,299 - 1,000 Ohms | -3 |
| Less Than 1,000 Ohms | -4 |

| pH Value | |
|---|---|
| Greater than 6 | 0 |
| Less than 6 | -1 |

| Sulfides | |
|---|---|
| Not Present | 0 |
| Trace, Less than 0.5 mg/kg $S^2$ | -2 |
| Present, Greater Than or Equal to 0.5 mg/kg $S^2$ | -4 |

| Sulphates | |
|---|---|
| Less than 200 mg/kg | 0 |
| 200 - 500 mg/kg | -1 |
| 501 - 1,000 mg/kg | -2 |
| Greater than 1,000 mg/kg | -3 |

| Water Level | |
|---|---|
| Within the 100 year flood plain | -2 |
| Within a delineated wetland or stream | -4 |
| Seasonally within the water table | -5 |
| Always within the water table | -2 |
| No Water | 0 |

## Figure 1 - Soil Parameter Scoring

**Step 3: Stray Currents** Stray current risks for all classes of pipelines shall be identified and evaluated by the designer. The potential for stray currents will be determined using the database of impressed current systems, maintained by the Nation Association of Corrosion Engineers (NACE), Baltimore-Washington Chapter; and using information from the owner of the facility carrying the current. Mitigation measures will be incorporated into the design of the proposed pipe. Consider worker safety near high voltage electric lines, possibly include ground mats to discharge current near above ground metallic features.

One or more of the following mitigation methods may be applied during construction if stray current is anticipated.

- Installing strategically placed sacrificial anodes;
- Installing test wires for draining current through electrical bonds;
- Installing dielectric mats between the two pipelines;
- Increasing the distance between the two pipelines;
- Applying a high-quality coating on both pipelines;
- Utilizing nonmetallic pipeline material for that short section;
- Installing metallic pipelines in nonmetallic casings;
- Modifying the design of the pipe to minimize susceptibility to stray currents; and
- Installing zinc grounding cells or solid-state devices; e.g., SSD.

**Stray current shall be assumed within 100' of high voltage electric lines (anything over 750 Volts), electric substations, metro rail lines, impressed current gas lines, or any other current producing line or structure.**

**Step 4: Evaluation** Using the information collected in Steps 1, 2, and 3, Loudoun Water will determine the level of corrosion protection to be included in the pipeline design. The decision process is included in **Figure 2**. Loudoun Water reserves the right to adjust the decision process as necessary based on project-specific conditions.

All Class 0 pipelines, and Class 1 pipelines in highly corrosive soils (Class A) will require a project-specific corrosion protection design. The design shall be prepared by an AMPP Certified Cathodic Protection Technologist Level III or Specialist Level IV if a cathodic protection system is deemed necessary. Otherwise, an AMPP Certified Protective Coating Specialist with water main corrosion control experience of at least 10 years will be required for the design, and incorporated into the construction plans and specifications for the proposed pipe.

Class 1 pipelines in moderately corrosive soils (Class B) and all Class 2 pipelines will require enhanced corrosion control protection. This includes stray current mitigation as necessary (which might include cathodic protection design to drain current away from pipe), wrapping in polyethylene encasement, and coating of mechanical joints.

Class 3 pipelines will be installed in accordance with standard Loudoun Water installation requirements including the coating of mechanical joints. With the exception of stray current mitigation where necessary.

Note: The use of heavy wall PVC Pipe in highly corrosive soils where only straight pipe sections are necessary and there are no lateral connections is acceptable. This is especially useful for wastewater force mains. See the *Approved Materials List* (Appendix G) for acceptable dimension ratios.

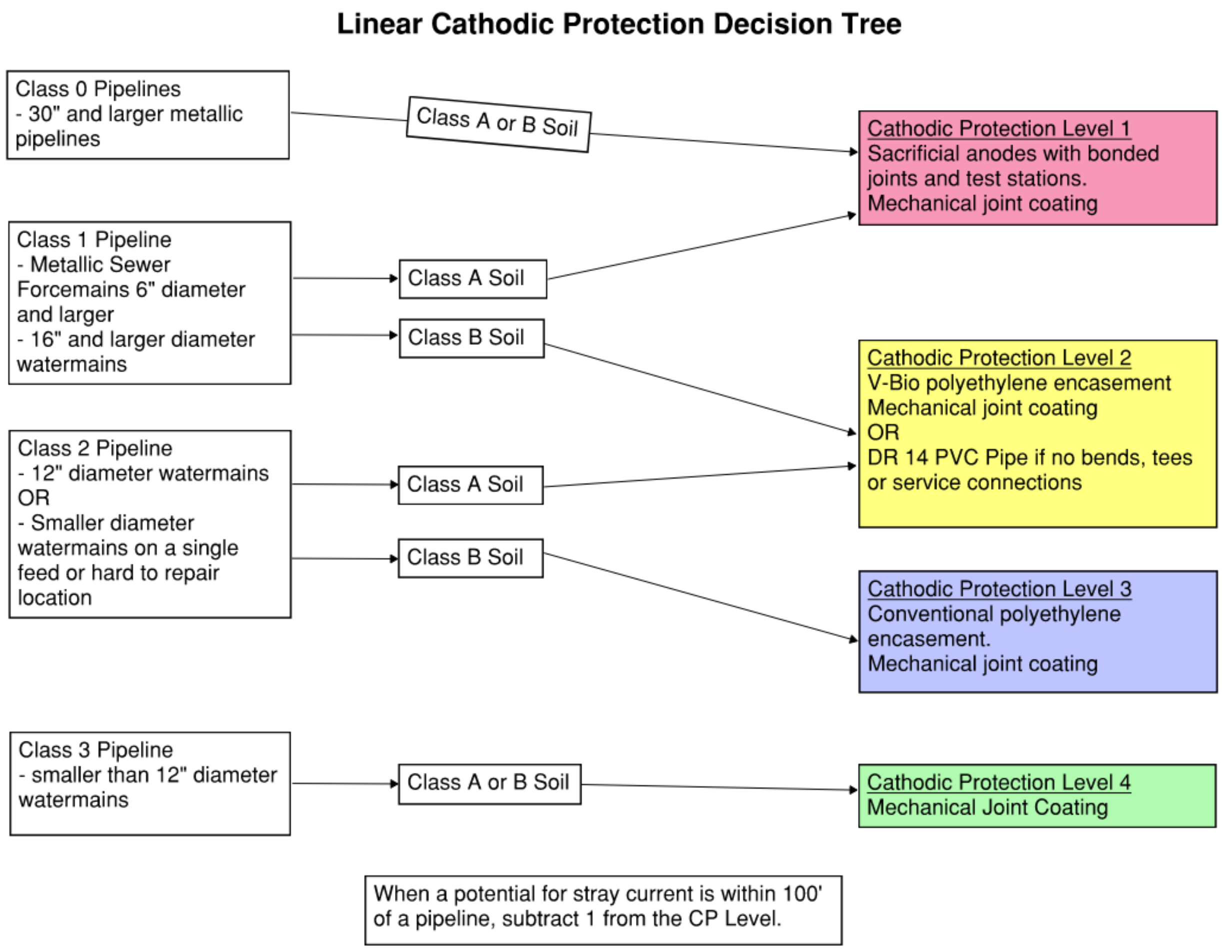


**Figure 2 - Decision Tree**

## III. Cathodic Protection or Corrosion Protection Monitoring Installation Requirements

All installations of corrosion control measures shall be made according to the approved construction plans and specifications for the project, the *Standard Details* and the *Approved Materials List* (Appendices F and G of this Manual). Upon completion of the work, it shall be tested, operated, inspected and surveyed. Any and all repairs or replacement of defective or improperly installed corrosion control systems shall be made by the contractor, at no additional cost to Loudoun Water.

### A. Contractor Qualifications

1. Installation, quality assurance, and testing personnel must have demonstrated experience with similar work. Resume of work experience shall be submitted to the Loudoun Water for approval in the cathodic protection submittal.

2. Personnel shall be specifically named in qualification submittal and have completed at least three successful corrosion control systems within the last three years for underground pipelines of similar type, similar size and equal complexity.

3. Contractor shall obtain the services of a Corrosion Engineer to inspect, activate, adjust, and evaluate the effectiveness of the cathodic protection system. The Corrosion Engineer is herein defined as a registered Professional Engineer with certification or licensing that includes education and experience in cathodic protection of buried or submerged metal structures, or a person accredited or certified by NACE at the level of Corrosion Specialist or Cathodic Protection Specialist (i.e., NACE CP Level 4). Such a person shall have not less than five years' experience inspecting pipeline cathodic protection systems.

4. The Contractor shall obtain the services of a Cathodic Protection Technician to inspect, activate, adjust, and evaluate the effectiveness of the cathodic protection system. The Cathodic Protection Technician is herein defined as a person accredited or certified by NACE as a Cathodic Protection Technician (NACE CP Level 2). Such a person shall have not less than five years' experience inspecting pipeline cathodic protection systems.

5. Personnel shall be a full-time contractor or subcontractor employee. Part-time or contract personnel hired only for this work will not be permitted.

6. Only personnel approved by Loudoun Water shall be permitted. Personnel changes during course of project must be minimized and proposed resume submitted to Loudoun Water at least two (2) weeks prior to planned implementation.

7. The contractor shall oversee and certify installation and related testing, including pipe joint bonding, magnesium anode ground-beds, and corrosion control equipment.

8. The contractor shall issue a letter of compliance indicating all corrosion control measures are satisfactorily installed and are in compliance with contract documents. The letter of compliance shall be signed by the contractor's responsible person.

**B. Thermite Welding**

1. All thermite welds shall be made as shown on Figure CP-2 of the *Standard Details* and in accordance with the manufacturer's recommendations using the proper combination of equipment for the pipe and wire size being welded. All welding materials and equipment shall be the product of a single manufacturer.

2. Assure that the area where the attachment is to be made is absolutely dry. Remove mill coating, dirt, grime, and grease from the pipe or fitting surface at the weld location by wire brushing or by the use of suitable safety solvents. Clean a two-inch square area of the pipe or fitting surface at the weld location to a bright shiny surface, free of all serious pits and flaws by the use of a mechanical grinder.

3. Prepare the wire for welding by assuring that the cable is absolutely dry. The cable shall be free of dirt, grease, and other foreign products. Cut the cable in such a way as to avoid flattening or forcing it out of round. To prevent deformation of the cable, cut the cable with cable cutters. Remove the insulation in such a manner that will avoid damage to strands. Install adapter sleeves for all bonds and test wires prior to welding. Either prefabricated factory sleeved joint bonds or bond wires with formed sleeves made in the field are acceptable. Hold the cable at an approximate 30 degree angle to the pipe surface when welding.

4. When the weld has cooled, tap with the two pound hammer while pulling firmly on the wire. This is done to assure the weld is well bonded to the pipe. If the weld dislodges from the pipe, it must be redone. Remake unsound welds and retest. Thoroughly clean mold and mold covers after completion of each weld to assure that no slag will penetrate into the next weld.

5. After the soundness of the weld has been verified, thoroughly clean the weld with a stiff wire brush and coat with an elastometric cap. Apply primer over the entire weld area. Push the dome of the prefabricated cap containing elastometric material firmly into the weld area. Lift the wire away from the pipe and apply the elastometric material coating completely around and underneath the wire. Push the wire back down on the pipe.

**C. Prepackaged Anodes**

1. The prepackaged anodes shall be installed where indicated on the *Standard Details* and the plans. Prior to installation, remove all shipping covers from the anode (the packaged bag and box shall not be removed). Install the anodes in existing soils (free from rocks, roots, organic material, trash or any other debris) and backfill with existing soil (as described above). Do not install the anode in sand, rock, or gravel backfill. Do not lower the anode into the excavation by the lead wire. If necessary, temporarily wrap a rope around the anode and lower the anode into the excavation by the rope. Remove the rope after the anode is installed. Provide a minimum spacing of two feet from other pipelines. Pre-soak the anode with 5 gallons of water after placement, but prior to backfilling.

2. Anode header cable shall be buried a minimum of 18 inches below grade. Handle wire with care. All anode lead wire to header cable splices shall be made with a compression connector as shown in detail CP-5 of the *Standard Details*. Tape the splice with three layers of high voltage rubber splicing tape (50% overlap). Terminate the ends of the anode lead cable in the test stations in accordance with the *Standard Details*.

**D. Bonded Joints**

1. All pipeline joints within the cathodic protection areas, including those on pipe, fittings, valves, and all branch connections, shall be bonded with two insulated copper cables as shown in detail CP-1 of the *Standard Details* where indicated on the plans.

**E. Test Stations**

1. Install test stations at the locations required. Test stations are to be located directly over the pipeline except in areas that would place the station in the roadway. Locate these test stations to the closest point at the edge of the road. Test station pedestals or boxes shall be in accordance with details CP-6, CP-7, CP-8, CP-9, and CP-10 of the *Standard Details*. Pedestals will be used where suitable to their surroundings and test boxes will be used where test station must be flush with the surrounding grade. A marker ball will be added at all test stations.

2. Attach test wires as indicated using the proper thermite welding equipment and charges specified for the wire size and respective pipe material. Follow all procedures as outlined above.

3. All test station wires shall be routed a minimum of 18 inches below finish grade. Maintain sufficient slack in the test wires so that the wires can extend a minimum of 18 inches from the compression thermal lugs for 0.25 inch bolt size. Install a shunt to connect the anode lead to the pipe lead where indicated on the design drawings.

4. All test station wires shall be in a 3" schedule 40 PVC conduit where they exit the pipe bedding stone until they reach the base of the test station.

5. The test station boxes shall be set in poured concrete in accordance with detail CP-11 of the *Standard Details*. Cathodic protection test station pad concrete shall be Class B concrete. The flush mounted test station lids shall be free of concrete and not cemented over.

6. A cathodic protection coupon, the same material as the pipe under cathodic protection, shall be installed at every third test station in order to remove the IR drop error.

**F. Clearance Requirements**

1. A minimum of 12" separation shall be maintained between a cathodic test station and any foreign pipeline or structures. If 12" separation is not possible, positive separation shall be provided using glass mesh as detailed on *Standard Detail* CP-15.

## G. Electrical Isolation

1. Insulating Flanges: Approved insulating flanges shall be installed in accordance with specific design considerations as shown on *Standard Detail* CP-17. See *Approved Materials List* for more information on specifications for insulation.

2. Pipe flange insulating kit materials shall be designated by the manufacturer as suitable for service at the operating temperatures and pressures of the pipeline.

3. Flange insulating kits shall consist of: a one-piece, full-face, insulating gasket; an insulating sleeve for each bolt; insulating washers; and steel washers. For nominal pipe diameters up to, and including, 36 inches, provide one insulating washer and one steel washer on each side of the flange for each flange bolt. For nominal pipe diameters greater than 36 inches, the insulating washers shall be installed sandwiched between a pair of matching steel washers on each side of the flange for each flange bolt.

4. Dielectric Pipe Materials: Approved dielectric pipe materials shall be used to isolate metallic pipe where specified as part of design consideration for foreign pipeline crossings as part of stray current mitigation considerations. A section of polyvinyl chloride (PVC) pipe may be a suitable material for this purpose. Pipe materials, thickness design, and pipe specifications shall be provided by the pipe design engineer and adhere to the *Approved Materials List*.

## H. Reference Electrodes

1. The reference electrode shall be a permanent copper/copper sulfate reference electrode (CSE) as listed in the *Approved Materials List*. No splicing of the reference electrode lead wire shall be permitted under any circumstances.

## I. Trench Excavation

1. The trench and backfill material around the pipeline shall be clean of all debris, such as trash, wood, and rocks. Strip forms at blockings.

2. Complete excavations and trenching, regardless of the type, nature, or condition of materials encountered, as required to accomplish specified construction to lines and grades shown.

3. Take care to avoid damage to existing structures and utilities during excavating and trenching process. Contractor may modify location, as approved by the design engineer and Loudoun Water, to minimize possible damage to existing structures. Trenches shall be of uniform depth and width, level, smooth, and free of sharp objects.

4. Slope, shore, or brace excavations and trenches, in accordance with OSHA regulations, as necessary, to prevent caving during excavation in unstable material, and to protect adjacent structures, property, workers, and the public.

5. Securely attach identification tags to all wires with nylon fasteners prior to backfilling operations.

6. Backfill trench with excavated backfill materials, if suitable. Suitable backfill shall be free of angular rock, debris, roots, turf, or other deleterious materials.

7. Do not use backfill material of frozen or consolidated debris. Leave the trench with the excess backfill material neatly mounded at not more than 4 inches above the existing ground level for the entire width of the trench.

## III. Post-Installation Quality Assurance and Acceptance Testing for Cathodic Protection

After the installation is complete, a third party testing agency AMPP or NACE Certified Cathodic Protection Technologist Level III will conduct the following post-installation quality assurance and acceptance testing, to verify the work. The repair or replacement of any defective or improperly installed systems shall be the sole responsibility of the contractor.

### A. Cathodic Protection System Activation

1. The CONTRACTOR's Corrosion Engineer and Cathodic Protection Technician shall inspect, activate, and adjust the cathodic protection system. The Cathodic Protection Technician shall work under the direct supervision of a Corrosion Engineer, as defined by this specification.

2. The Corrosion Engineer shall evaluate whether there are any stray currents affecting the water pipeline. If stray currents are present and affecting the water pipeline, and if there is the possibility that the current can cause detrimental corrosion, then the cathodic protection system's performance shall be evaluated.

3. Do not proceed with the cathodic protection system activation until the reports for the following have all been submitted and accepted as complete by Loudoun Water:

   a. Insulated Flange/Joint Inspection Report;

   b. Electrical Isolation Testing Between Pipe and Steel Reinforcement Report;

   c. and Baseline (Native) Potential Survey Report.

   d. Provide a minimum of five days' advance notice to Loudoun Water before the cathodic protection activation will be performed to allow for coordination and observance of these tests.

4. Before beginning each day of testing, calibrate portable copper/copper sulfate reference electrodes with respect to a master reference copper/copper sulfate reference electrode.

5. Measure and record native pipe-to-soil potentials (i.e., baseline pipe-to-soil potentials), if applicable, at all cathodic protection test stations prior to activating the cathodic protection system. Measure native potentials on both sides of all insulating flanges, at the dielectric unions and at all test station wires. Measure the native potentials of electrically grounded equipment inside all vaults and structures along the pipeline. Where two wires are attached to the same pipeline, measure and record the native potentials for both wires. If the potential measurements for the same pipeline differ by more than 5 millivolts, investigate the cause. All test measurements shall be in accordance with NACE TM497.

6. At test stations constructed with buried copper/copper sulfate reference electrodes (i.e., stationary reference electrodes), measure and record native potentials of the pipeline and coupon using both the stationary reference electrode and a portable copper/copper sulfate reference electrode before the cathodic protection system is activated.

7. Measure the potentials of all galvanic anodes before they are connected to the pipe. Verify that the open-circuit potential of each high-potential magnesium anode is more electro-negative than –1.65 volts. While making these measurements, place the copper/copper sulfate reference electrode in the soil directly over the anode hole.

8. Activate the cathodic protection system by connecting all of the anode wires to the terminals inside each test station.

9. Measure and record "On" potentials at the same locations where native potentials were previously measured.

10. Measure and record the initial current of each anode ground bed using a portable digital meter. Measure and record the individual anode current outputs. Next, bond the anode lead wires to the pipe lead wires and measure the "On" potentials.

11. Resurvey the cathodic protection system at least two weeks after the initial energization to allow for the development of the cathodic polarization process.

12. Use the most recent current output of each anode ground bed to calculate the anode replacement dates, assuming continued uniform current outputs and the appropriate anode alloy consumption rate. Assume an 85% utilization rate for all anode ingots.

13. Furnish all test results, including all potential readings, anode ground bed current readings, insulating flange test data, wire testing data, continuity testing, electrical isolation data, structure-to-earth potential testing data, anode operating current data, dates, and times. Reference all data to the pipeline name and station number from which it was taken/observed. Submit all data, along with a letter report, to Loudoun Water. The letter report shall include a description of the test methods, analysis of the data, and conclusions about the cathodic protection system's effectiveness. Submit all data in a spreadsheet format compatible with Microsoft Excel. Submit data in both hard copy and electronic format.

14. Prior to substantial/beneficial completion, the third party testing agency shall perform post-installation testing of all cathodic protection components. The repair or replacement of any defective or improperly installed components shall be the sole responsibility of the CONTRACTOR. Any and all repairs or replacement of defective or improperly installed cathodic protection components shall be performed by the CONTRACTOR and at no additional cost to Loudoun Water.

15. Prior to final completion the third party testing agency shall verify the results from the substantial/beneficial testing. The CONTRACTOR shall repair or replace any defective or improperly installed components prior to acceptance by the OWNER.

**B. Test Station Wires**

1. All test station wires shall be field verified for electrical continuity after connection of the wires on the terminal board in the test station and prior to the installation of any shunts on the terminal board. The testing will verify that the test wires have been properly installed and have not been damaged during backfilling and final test station installation. The test station wire verification shall be performed with an industry standard high impedance voltmeter and a copper/copper sulfate reference electrode.

2. The test station wire verification shall be performed by placing a copper/copper sulfate reference electrode in the soil adjacent to the test station being tested. Connect the copper/copper sulfate reference electrode to the positive terminal of the voltmeter with a test lead. Connect the test wire to be verified to the negative terminal of the voltmeter with a test lead. Record the resultant structure-to-earth potential. Without moving the copper/copper sulfate reference electrode, repeat this measurement for every wire in the test station.

3. Acceptance criteria shall be as follows:

   a. Ductile iron pipe typically has a voltage to ground potential of between -0.50 and -0.65 volt to a copper/copper sulfate reference, these potentials can vary depending on the soil composition, pipe coating or bare, moisture, and soil compaction. Adjacent test leads on the pipe shall have the exact same potential. Voltage to ground measurements outside of this range will require further evaluation, to determine if stray currents are affecting the pipeline.

   b. Magnesium anodes whether standard or high potential shall be either -1.50 or -1.65 volts, respectively, to a copper/copper sulfate reference. Voltage to ground measurements below this range will require further evaluation and may not be accepted.

   c. The criteria used to evaluate the protection levels shall be as listed in NACE SP0169.

4. Results of the test wire verification testing shall be documented. Documentation shall include the following:

   a. Name and company of the Corrosion Technician performing test;

   b. date of each test;

c. station number of test wires;

d. test wire color and size;

e. structure that the test wire is connected to;

f. structure-to-earth potential for each test wire;

g. statement that the test wire has been installed properly in accordance with the criteria listed above. Data shall be maintained for inclusion in the final quality assurance report.

**C. Casings**

1. Test for electrical isolation between any metallic pipeline and metallic casing in accordance with NACE SP0286.

2. Prior to and upon completion of backfilling operations, test the electrical isolation between the pipeline and all casings the pipe passes through to ensure the casing is not electrically shorted to the pipeline. If the casing is found to be electrically shorted, or electrolytically coupled to the pipeline, the CONTRACTOR shall correct the deficiency at the CONTRACTOR's expense.

**D. Reinforced Concrete Structures**

1. Under no circumstances shall metallic pipe be in contact with reinforcing steel.

2. Position reinforcing steel used in the construction of support blocks, anchor blocks, and any and all other concrete structures so that they are not in contact with the piping. Maintain a minimum clearance of 2 inches between the piping and all reinforcement steel or other metallic components. Under no circumstances shall metallic pipe be in contact with reinforcing steel, in accordance with NACE SP0286. If sufficient clearance cannot be provided, then an insulating blanket may be required between the pipe and reinforcing steel.

3. Carrier pipe shall be electrically discontinuous from any concrete structure and from any metallic wall sleeve.

**E. Linear Electrical Continuity**

1. The linear electrical continuity of the bonded water main shall be tested to confirm that pipe joint bond cables have been properly installed and have not been damaged during backfilling. The testing will verify that the water main is electrically continuous in accordance with design specifications.

2. The linear electrical continuity testing shall be performed with a combination voltmeter/ammeter, a 12-volt battery capable of at least 80 amperes short circuit current, and test wires and leads of sufficient length to extend over the length of pipe being tested.

3. The linear electrical continuity testing shall be performed by impressing a DC current between adjacent test stations while simultaneously measuring the resultant voltage drop on the pipeline between the adjacent test stations. Voltage and current measurements shall be recorded with the current applied and immediately after the current is turned off.

4. Calculate the voltage and current delta readings for each measurement by subtracting the "Instant Off' values from the "Current On" values. Divide the voltage delta by the current delta to calculate the measured resistance value.

5. Calculate the theoretical resistance of the pipe section using published resistance tables for the type and diameter of the pipe that was installed. Multiply the length of the pipe being tested by the resistance value for the type and size of pipe being tested. Determine the number of pipe joints in the section being tested. Multiply the number of pipe joints by the theoretical resistance of the bond wires that were installed. Add the resistance value for the length of pipe to the resistance value for the pipe joints to determine the theoretical resistance value of the section of pipeline being tested.

6. Compare the measured resistance value to that calculated resistance value for the test section. The measured linear electrical resistance of the test section will be acceptable if the measured resistance value is no greater than 115% of the theoretical linear resistance value for the test station.

7. Repeat the above test procedures between all adjacent test stations on the water main until the entire length of pipeline is tested. Actual resistances greater than 115% of the theoretical resistance will have to be re-evaluated to assure adequate electrical continuity of the pipe span.

8. Results of the linear continuity testing shall be documented. Documentation shall include the following:

   a. Name, and company, of the Corrosion Technician performing test;

   b. date of each test;

   c. beginning and end station numbers of test section;

   d. length of the test section;

   e. amount of current applied for the test;

   f. voltage drop measured over the test section with current applied;

   g. voltage drop measured over the test section immediately after the current is turned off;

   h. calculated measured resistance of the test section;

   i. type and diameter of pipe;

   j. theoretical resistance per foot of pipe length;

k. length, size and number of bond cables per joint;

l. calculated resistance of bond cables across one joint;

m. number of pipe joints in test section;

n. calculated theoretical resistance of the entire pipe section;

o. percentage that the measured resistance is greater than or less than the theoretical resistance of the pipe section;

p. statement that the section of pipe has been properly bonded in accordance with acceptance criteria listed above. Continuity data shall be maintained for inclusion in the final quality assurance acceptance report.

### F. Electrical Isolation

1. All insulating couplings, insulating flanges, insulating unions and insulating casing spacers shall be tested to confirm that effective electrical isolation exists between the isolated structures. The testing will verify that the insulating couplings, flanges, unions and casing spacers have been installed properly and are providing effective isolation.

2. The electrical isolation testing shall be performed with a high impedance combination volt/ammeter, a copper/copper sulfate reference electrode, a 12-volt battery and test leads of sufficient length to obtain structure-to-earth potentials and apply current to each side of the insulator.

3. The effectiveness of the electrical isolation shall be verified by measuring structure-to-earth potentials of each side of the insulator while a DC current is applied between one side of the insulator and a temporary ground-bed. Install a temporary ground-bed by inserting steel pins into the ground directly over the pipeline and approximately 50 feet from the insulator being tested. Impress a DC current between the temporary ground-bed and the opposite side of the insulator. Using a portable reference electrode placed over the insulator, measure the structure-to-earth potential on each side of the insulator. Structure-to-earth potentials shall be measured with the current applied and immediately after the current is turned off. Structure-to-earth and current readings shall be obtained simultaneously. Record the potential and current data.

4. Effective electrical isolation of the insulating coupling, insulating flange, insulating union or insulating casing spacers will be indicated by a negative potential shift ("On" reading minus the "Instant Off' reading) on the side of the insulator closest to the ground-bed. The far side of the insulator will have a positive voltage shift ("On" reading minus the "Instant Off' reading) if the test circuit is set up properly.

5. Results of the electrical isolation testing shall be documented. Documentation shall include the following:

   a. Name, and company, of the Corrosion Technician performing test;

   b. date of each test;

c. station number of electrical isolation;

d. location and type of insulator tested;

e. pipe-to-earth potentials ("On" and "Instant Off' values) on both sides of the insulator;

f. test current ("On" and "Instant Off' values);

g. statement that the electrical isolation is effective. Electrical isolation data must be maintained for inclusion of the final quality assurance acceptance report.

**G. Cathodic Protection and Stray Current Mitigation Potentials**

1. For pipelines with cathodic protection and/or stray current mitigation anodes, testing shall be performed to evaluate the effectiveness of the anodes. Base structure-to-earth potential data shall be obtained at all test stations before any anode lead wires are connected to the pipe leads. The initial operating structure-to-earth potentials shall be obtained at each test station immediately after installing the shunts between the pipe and the anode leads. The base and initial operating potentials shall be measured with a high impedance digital voltmeter and a copper/copper sulfate reference electrode.

2. The structure-to-earth potential between the pipeline test lead wire, which is not directly connected to the anode leads in the test station, and a portable copper/copper sulfate reference electrode contacting the soil shall be measured, using the voltmeter. The portable electrode shall be placed adjacent to the test station for the measurement. Connect the copper/copper sulfate reference electrode to the positive terminal of the voltmeter with a test lead and connect pipeline test wire to the negative terminal of the voltmeter with a test lead. Obtain structure-to-earth potentials ("On" values) on all test wires with the anode leads connected to the pipe.

3. Results of the structure-to-earth potential testing shall be documented. Documentation shall include the following:

   a. Name, and company, of the Corrosion Technician performing test;

   b. date of each test;

   c. station number of test wires;

   d. structure-to-earth potentials ("Native Potentials") on each test wire;

   e. structure-to-earth potentials ("On potentials") on all test wires with all anode lead wires connected to the appropriate pipe leads in all test stations;

   f. structure-to-earth potentials ("Instant Off Potentials") on all test wires immediately after the anode leads at the test station are temporary disconnected (testing performed with all other anode ground beds connected in their respective test stations and after the piping has had a minimum of one month to polarize);

g. statement that the corrosion control system is operating in accordance with the designed corrosion control plan. Potential data shall be maintained for inclusion in the final quality assurance acceptance report.

**H. Anode Operating Current**

1. Initial anode operating current shall be measured at each test station where anodes are installed. The initial anode operating current shall be measured using the test station shunt and a digital voltmeter. The anode current shall be measured by connecting the positive terminal of the millivolt meter to one side of the shunt and the negative terminal of the millivolt meter to the other side if the shunt. The millivolt reading shall be obtained and recorded. Using the calibration factor of the shunt, calculate the anode current in milliamps. The anode current will be equal to the voltage reading across the shunt divided by the resistance of the shunt. Record the calculated current output of the anodes.

2. Results of the initial and final anode operating current testing shall be documented. Documentation shall include the following:

   a. Name, and company, of the corrosion technician performing tests

   b. date of each test

   c. station number of anode test wires

   d. initial anode current output (shunt measurement)

   e. final anode current output (shunt measurement), testing to performed with all other anode ground-beds connected in their respective test stations and after the piping has had a minimum of one month to polarize

   f. statement that the anodes are operating in accordance with the design documents. Anode current data shall be maintained for inclusion in the final quality assurance acceptance report.

**I. Close-Interval Potential Survey**

1. At final completion, AMPP technician shall conduct a close-interval survey on the pipeline. Close interval potential survey data will be used to evaluate the effectiveness of applied cathodic protection.

2. Where applicable all cathodic protection sources shall be interrupted to obtain a polarized potential (IR Free) measurement. Where the current sources cannot be interrupted obtain polarized potential at all coupons.

3. The close-interval potential survey shall be performed using a high impedance voltmeter, a copper/ copper sulfate reference electrode, test lead wire long enough to survey the test area, and associated clips and test leads.

4. Connect the high impedance voltmeter between the pipe leads in a test station and the copper/copper sulfate reference electrode. The voltmeter is reconnected to the pipeline at

each test station along the pipeline. The Corrosion Technician places the electrodes in contact with the earth directly over the pipeline and the structure-to-earth potentials at that point are recorded. The reference electrode is then placed approximately 5 feet away from the site of the first reading and the measurement is recorded. This process continues along the entire pipeline route and potential data are collected and recorded every 5 feet.

5. The data that were collected are then tabulated and entered into a database to be graphed. The tabulated data and graphs are then submitted for analysis by the NACE certified corrosion specialist.

6. Results of the close-interval potential survey shall be documented. Documentation shall include the following:

   a. Name, and company, of the Corrosion Technician performing test;

   b. date of the test;

   c. tabulated pipe-to-earth with station numbers, test stations and features identified;

   d. graphed profile data with station numbers, test stations and features identified on the graph;

   e. statement that the corrosion control system is operating in accordance with the design considerations. Close interval survey data shall be maintained for inclusion in the final quality assurance acceptance report.

### J. Record Drawings

Record Drawings will be prepared to accurately document the installed location and configuration of each test station, including:

1. test station number and type per the test station schedule on the plans and installed pipeline station number.

2. three dimensional ties between test station and existing permanent datum.

3. wire routing, size, insulation color and termination configured on terminal board.

4. pipeline station numbers for wire attachments to pipe.

5. anode locations, where installed, including pipeline station number, depth and distance from pipe.

6. Coupon depth and location if installed.

7. Polyethylene encasement limits and type installed.