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Standard Practice

External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

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Foreword

This standard presents standard practices for effective control of external corrosion of underground storage tank (UST) systems by cathodic protection (CP). It is intended to be used by corrosion professionals as a guideline to establish minimum requirements for using CP to control external corrosion of metallic UST systems, including those used to contain oil, gas, and water. Specifically addressed is CP of:

(a) Existing bare and externally coated steel USTs;

(b) New externally coated steel USTs;

(c) Metallic piping and flexible connectors; and

(d) Other metallic components.

For further information on testing CP systems for UST systems, refer to NACE Standard TM0101.[1]

This standard was originally published in 1985 by Task Group (TG) T-10A-14, "Control of External Corrosion on Metallic Buried, Partially Buried, or Submerged Liquid Storage Systems." The standard was revised in 1995 by TG T-10A-14, "Corrosion Control of Underground Storage Tank Systems," a component of Unit Committee T-10A, "Cathodic Protection." It was revised in 2002 and in 2011 by TG 011, "Corrosion Control of Underground Storage Tank Systems by Cathodic Protection." TG 011 is administered by Specific Technology Group (STG) 35, "Pipelines, Tanks, and Well Casings," and is sponsored by STG 05, "Cathodic/Anodic Protection." This standard is issued by NACE International under the auspices of STG 35.

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NACE International
Standard Practice

External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection

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Section 1: General

1.1 Introduction

1.1.1 This standard presents standard practices for effective control of external corrosion of UST systems by CP. It is intended to serve as a guideline to establish minimum requirements for using CP to control external corrosion of metallic UST systems, including those used to contain oil, gas, and water, and that are buried, partially buried, or in contact with the soil.

1.1.2 When designing the CP system, the designer shall provide the owner with the design life and the assumptions used to develop the CP system design. If conditions change at the UST site, the original CP system design life may also change. Some examples of UST system changes include fluctuation in soil resistivity, UST system coating failure, adding/removing components of the UST system or site, and electrical shorting or isolation of UST components. This information should be kept as part of the permanent UST system records.

1.1.3 This standard does not designate specific practices for every situation because the complexity of some environmental conditions in which UST systems are buried precludes standardization of corrosion control practices.

1.1.4 This standard does not include corrosion control methods based on chemical control of the environment, internal linings, or the use of UST construction materials other than steel.

1.1.5 This standard does not override applicable safety codes and should not be used to infringe on the primary requirement of protecting personnel, the environment, and equipment. In any situation, the CP system design for UST systems should incorporate all requirements of any applicable codes, standards, and regulations as determined by authorities having jurisdiction.

1.1.6 The provisions of this standard shall be applied under the responsible direction of competent individuals. Such individuals must either be registered professional engineers, NACE International certified Corrosion Specialists or CP Specialists, or individuals qualified by professional education and related practical experience. All of the above individuals must be able to demonstrate suitable experience in corrosion control of UST systems.

1.1.7 Deviation from this standard may be warranted in specific situations provided the objectives expressed in this standard have been achieved.

1.1.8 For accurate and correct application of this standard, this standard must be used in its entirety. Using or referring to only specific paragraphs or sections can lead to misinterpretation and misapplication of the standard practices contained in the standard.

Section 2: Definitions

Anode: The electrode of an electrochemical cell at which oxidation occurs. (Electrons flow away from the anode in the external circuit. It is usually the electrode where corrosion occurs and metal ions enter solution.)

Backfill: Material placed in a hole to fill the space around the anodes, vent pipe, and buried components of a cathodic protection system.

Cathode: The electrode of an electrochemical cell at which reduction is the principal reaction. (Electrons flow toward the cathode in the external circuit.)

Cathodic Disbondment: The destruction of adhesion between a coating and the coated surface caused by products of a cathodic reaction.

Cathodic Polarization: (1) The change of electrode potential caused by a cathodic current flowing across the electrode/electrolyte interface; (2) a forced active (negative) shift in electrode potential. (See *Polarization*.)

Cathodic Protection: A technique to reduce the corrosion rate of a metal surface by making that surface the cathode of an electrochemical cell.

Coating: (1) A liquid, liquefiable, or mastic composition that, after application to a surface, is converted into a solid protective, decorative, or functional adherent film; (2) (in a more general sense) a thin layer of solid material on a surface that provides improved protective, decorative, or functional properties.

Continuity Bond: A connection, usually metallic, that provides electrical continuity between structures that can conduct electricity.

Corrosion: The deterioration of a material, usually a metal, that results from a chemical or electrochemical reaction with its environment.

Corrosion Potential: (Represented by the symbol E_{corr}) The potential of a corroding surface in an electrolyte measured under open-circuit conditions relative to a reference electrode. (Also known as *Electrochemical Corrosion Potential*, *Free Corrosion Potential, Open-Circuit Potential.)*

Current Density: The electric current flowing to or from a unit area of an electrode surface.

Dielectric Coating: A coating that does not conduct electricity.

Dissimilar Metals: Different metals that could form an anode-cathode relationship in an electrolyte when connected by an electron-conducting (usually metallic) path.

Driving Potential: Difference in potential between the anode and the steel structure.

Electrical Isolation: The condition of being electrically separated from other metallic structures or the environment.

Electrochemical Cell: (1) an electrochemical reaction involving two half reactions, one of which involves oxidation of the reactant (product) and the other of which involves reduction of the product (reactant). (The equilibrium potential of the electrochemical cell can be calculated from the change in free energy for the overall electrochemical reaction. The equilibrium potential of the electrochemical cell can be measured by separating the oxidation and reduction half reactions into individual compartments and measuring the voltage that develops between them under conditions that virtually no charge passes between them.) [thermodynamic use]; (2) an electrochemical system consisting of an anode and a cathode in metallic contact and immersed in an electrolyte. (The anode and cathode may be different metals or dissimilar areas on the same metal surface.) [common use]

Electrode Potential: The potential of an electrode in an electrolyte as measured against a reference electrode.

Electrolyte: A chemical substance containing ions that migrate in an electric field. For the purposes of this standard, electrolyte refers to the soil or liquid adjacent to and in contact with a buried or submerged metallic UST system, including the moisture and other chemicals contained therein.

Foreign Structure: Any metallic structure that is not intended as a part of a system under cathodic protection.

Galvanic Anode: A metal that provides sacrificial protection to another metal that is more noble when electrically coupled in an electrolyte. This type of anode is the electron source in one type of cathodic protection.

Groundbed: One or more anodes installed below the earth's surface for the purpose of supplying cathodic protection current.

Impressed Current: An electric current supplied by a device employing a power source that is external to the electrode system. (An example is direct current for cathodic protection.)

Impressed Current Anode: An electrode, suitable for use as an anode when connected to a source of impressed current. (It is often composed of a substantially inert material that conducts by oxidation of the electrolyte and, for this reason, is not corroded appreciably.)

Instant-Off Potential: The polarized half-cell potential of an electrode taken immediately after the cathodic protection current is stopped, which closely approximates the potential without IR drop (i.e., the polarized potential) when the current was on.

Interference Bond: An intentional metallic connection, between metallic systems in contact with a common electrolyte, designed to control electrical current interchange between the systems.

IR Drop: See *Voltage Drop*.

Isolation: See *Electrical Isolation*.

Polarization: The change from the corrosion potential as a result of current flow across the electrode/electrolyte interface. For the purposes of this standard, polarization is considered to be the change of potential of a metal surface resulting from the passage of current directly to or from an electrode.

Polarized Potential: (1) (general use) the potential across the electrode/electrolyte interface that is the sum of the corrosion potential and the applied polarization; (2) (cathodic protection use) the potential across the structure/electrolyte interface that is the sum of the corrosion potential and the cathodic polarization.

Potential Gradient: A change in the potential with respect to distance, expressed in millivolts per unit of distance.

Reference Electrode: An electrode having a stable and reproducible potential, which is used in the measurement of other electrode potentials.

Stray Current: Current flowing through paths other than the intended circuit.

Stray-Current Corrosion: Corrosion resulting from stray current.

Structure-to-Electrolyte Potential: The potential difference between the surface of a buried or submerged metallic structure and the electrolyte that is measured with reference to an electrode in contact with the electrolyte.

Structure-to-Soil Potential: See *Structure-to-Electrolyte Potential.*

Underground Storage Tank (UST) System: The equipment and facility constructed, maintained, or used for underground storage of products including tanks, piping, pumps, and appurtenances associated with filling, storage, and dispensing of the stored products.

Voltage Drop: The voltage across a resistance when current is applied in accordance with Ohm's law. [also sometimes referred to as IR drop]

Section 3: Cathodic Protection of New Underground Storage Tank Systems

3.1 General

3.1.1 There are three basic types of CP systems available for new UST systems:

(a) Factory-fabricated galvanic anode systems;

(b) Field-installed galvanic anode systems; and

(c) Field-installed impressed current systems.

3.1.2 The standard practices for field-installed CP systems on new UST systems are similar to those for existing UST systems described in Section 4.

3.2 Factory-Fabricated Cathodic Protection Systems

3.2.1 Factory-Fabricated Galvanic Anode CP Systems

3.2.1.1 Factory-fabricated galvanic anode CP systems are available for new USTs. The design and specifications for the factory-fabricated galvanic anode CP systems consider three important factors:

(a) the galvanic anodes;

(b) a dielectric coating; and

(c) electrical isolation.

3.2.1.2 The components are designed together as a system to achieve corrosion protection for various UST sizes and most UST system site conditions. Bonding the UST to other structures may violate the manufacturer's warranty.

3.2.2 Anodes

3.2.2.1 Packaged zinc or magnesium anodes are used for factory-fabricated systems. Aluminum anodes usually are not effective in underground applications. The size and number of anodes required to protect a UST system from corrosion is predetermined by calculations based on the desired design life, the UST system surface area, the quality of the coating, anode type, anode size, and the range of soil resistivity in which it is anticipated the UST system will be installed.

3.2.2.2 The anodes may be attached directly to the UST system or wired through a test station to the UST system. Use of a test station allows the anodes to be disconnected from the UST system when testing. The type of anode used is determined by UST system site conditions and operational factors. Magnesium anodes shall be used on UST systems when the anode temperature exceeds 49 °C (120 °F).

3.3 Piping for New Underground Storage Tank Systems

3.3.1 Corrosion protection of all underground piping associated with the UST system can be achieved through a combination of material selection, system design, and coatings.

3.3.2 Piping within a secondary containment system may require other corrosion control methods in lieu of CP.

3.3.3 Several design parameters to be considered in selecting materials include:

(a) compatibility with the environment;

(b) compatibility with the product to be contained; and

(c) pressure and temperature.

3.3.4 Metallic Piping

3.3.4.1 Metallic piping in contact with an electrolyte shall be protected from external corrosion through the application of coatings and CP.

3.3.4.2 When available, factory-applied coatings should be used. The following standards may be helpful:

(a) For factory-applied coatings, refer to NACE Standard RP0185;[2] and

(b) For field-applied coatings, refer to NACE Standard RP0375.[3]

3.3.4.3 All metallic components to be cathodically protected should be made electrically continuous. When galvanic anode CP is used, all metallic components to be protected should be electrically isolated from all other metallic components.

3.3.4.4 Metal piping with mechanical joints may require bonding to ensure electrical continuity.

3.3.4.5 Practices for CP monitoring, including facilities and configurations, are given in Section 8.

3.3.4.6 Metallic secondary containment systems exposed to an electrolyte should be cathodically protected.

3.3.4.7 CP systems shall be designed to mitigate any adverse effects from stray current on foreign metallic structures within the influence of the CP system.

3.3.5 Nonmetallic Piping

3.3.5.1 Nonmetallic piping cannot be protected by CP; however, any metallic components of the product piping system that are exposed to soil shall be protected.

3.3.5.2 Materials selection should ensure product compatibility not only with the basic pipe material, but also with any adhesives or joint compounds.

3.3.6 Flexible Connectors

3.3.6.1 Flexible connectors are used on rigid piping systems to accommodate pipe movement. These connections, depending on materials of construction, may contain dissimilar metals that can cause corrosion in buried applications.

3.3.6.2 Flexible connectors may not provide electrical continuity. Verification and bonding may be required based on the CP system design.

3.3.6.3 All metallic components of the flexible connectors in contact with the electrolyte shall be cathodically protected. (Protection of flexible connectors is often overlooked in nonmetallic piping systems.)

3.3.6.4 Factory-fabricated CP systems are available for flexible connectors.

3.3.7 All CP systems should be monitored in accordance with Section 8.

3.4 Coatings

3.4.1 A high-quality dielectric coating should be applied to properly prepared external surfaces—in accordance with the coating manufacturer's recommendations—of the steel UST, including anode connections, attachments, and lifting lugs. Crevice or corner areas that restrict coating coverage should be seal welded prior to coating.

3.4.2 Any type of coating used on a steel UST must have high dielectric properties. The purpose of a dielectric coating is to isolate the UST electrically from the environment, while reducing protective current demands on the CP system. Other properties necessary in a dielectric coating are resistance to environmental fluids and the product being stored, impact/abrasion resistance, adhesion, and resistance to cathodic disbondment.

3.4.2.1 Three types of dielectric coatings commonly used on steel USTs are polyurethanes, epoxies, and reinforced plastics. Performance of these coatings should conform to a recognized industry standard such as:

(a) STI(1) T871;[4] or

(b) UL(2)1746,[5] Part 1, Section 10.

3.4.2.2 When flaws, damage, and degradation occur on coatings, these damaged areas must be repaired in accordance with manufacturer's specifications.

3.5 Electrical Isolation

3.5.1 A factory-fabricated cathodically protected steel UST shall be electrically isolated from all other metallic structures (product and vent piping, hold-down straps, liquid-level monitoring systems, interstitial space monitors, conduit lines, etc.) for the CP system to perform as designed. Electrical isolation of a factory-fabricated cathodically protected UST is required because the CP system design capacity is sufficient only for the UST. Electical isolation devices are normally installed at the manufacturing plant to eliminate installation errors and to be compatible with the product being stored. The device used to ensure electrical isolation is dependent on the type of connection being made to the UST. Electrical isolation devices should be used only within their temperature and pressure limitations.

3.5.1.1 Dielectric bushings are used for threaded connections in nonpressure USTs. These bushings shall be as specified in UL 1746, Part I, Section 11, and STI-P3,[6] or meet equivalent requirements.

3.5.1.2 Flanged connections are used when conditions preclude the use of dielectric bushings. Flange isolation kits should be used if flanged connections are to be made in the field.

3.5.1.3 If hold-down straps are to be used, effective isolation material shall be used between the strap and UST surface.

(1) Steel Tank Institute (STI), 944 Donata Ct., Lake Zurich, IL 60047.
(2) Underwriters Laboratories Inc. (UL), 333 Pfingsten Rd., Northbrook, IL 60062.

3.5.2 The electrical isolation should be verified after installation is completed but before backfilling and final paving or grading.

3.6 Backfill

3.6.1 The backfill shall be a homogeneous material that is compatible with the coating and CP system. The backfill material shall be free of rocks, trash, debris, ice, and other nonhomogeneous materials.

3.6.2 The CP design shall consider situations in which protective current flow is obstructed by geologic conditions or the presence of other structures.

3.7 Miscellaneous

3.7.1 USTs are often anchored to prevent buoyant forces from floating the USTs. Anchor materials shall consist of flat straps that are isolated from the UST surface with a dielectric insulating material. Wire cable or steel round bars should not be used because point-of-contact damage to the coating can occur. Corrosion control of the strap components shall be considered.

3.7.2 Each cathodically protected UST system should have the following:

(a) a dedicated test lead wire connected to the metallic structure;

(b) access to the electrolyte for portable reference electrode tests; and

(c) accessible connection points for all permanently installed monitoring devices.

Section 4: Cathodic Protection of Existing Underground Storage Tank Systems

4.1 Prior to initiation of the field testing necessary for design of the CP system, information concerning the history of the UST(s) to be cathodically protected should be assembled. This information generally falls into two groups: physical description and operating history. Although all information may not be available for every UST, as much information as possible should be obtained. This information can save field investigation time, resulting in a more cost-effective CP system, and can help to avoid an ineffective CP system design.

4.2 Physical Description

4.2.1 Size, Configuration, and Condition: The type of CP system and the amount of cathodic current required to protect the USTs and piping depends on the surface area, quality of coating on the structures, and the properties of the electrolyte. The configuration of the USTs and piping and their location with respect to other structures at the site may also affect the type of CP system selected.

4.2.2 Materials of Construction: Knowledge of the materials and construction of the USTs, piping, and related facilities is required to assess the probable corrosion mechanisms affecting the facilities and to determine which structures will require CP. The materials of construction include any buried portion of the UST system (e.g., valves, fittings, tank pads, straps, anchors, foundations, ground rods, cables, monitoring devices, the tank, and the piping). The use of dissimilar metals for the various components can accelerate corrosion on an unprotected UST system and can affect the current required for CP. The existence and condition of coatings on the metallic components also have a significant influence on the design of the CP system.

4.2.3 Electrical Continuity: The design and operation of CP systems are dependent on the extent of electrical continuity of the underground metallic structures. The existence of intentional bonding, grounding, or electrical isolation of underground metallic structures should be considered. Unnecessary electrical grounds should be considered for removal. The method of electrical joining of piping, tanks, and associated underground structures, including conduits, may affect the CP design.

4.2.4 Other Underground Structures: The presence of additional underground structures unrelated to the UST system can affect the feasibility, type, and capacity of the proposed CP system. The CP system designer must identify and take into account all such structures. Either cooperative interference testing must be performed between these structures, or the additional underground structures must be bonded into the UST system, or other corrective measures must be taken.

4.2.5 Pavement: The presence and thickness of pavement at the site can affect both the operation of the CP system and the cost of installation. The location, type, age, and probable repaving schedule are of interest to the CP system designer. The presence of other significant site improvements must be considered.

4.3 Operating History

4.3.1 The operating history of the UST system, including the date of installation and as-built drawings, provides important information for evaluation.

4.3.2 The results of tightness testing, internal inspection, or other industry recognized methods of integrity assurance should be analyzed (see API(3) Std 1631[7] and ASTM(4) G158[8] for additional information).

4.3.3 The leak history of the UST may influence the feasibility of the retrofit CP system. The date, location, and type of each leak should be assessed.

4.3.4 Repairs or replacements of UST system components should be analyzed as to their effect on the UST system's probability for corrosion or on the operation and effectiveness of the retrofit CP system. The reason for repairs, replacements, or system modifications, as well as the materials and methods used, should be analyzed.

4.3.5 Operating data of any previous CP system for the UST system, including the type of CP system (galvanic or impressed current), the date of installation, the type, size, and placement of anodes, and the level of CP, should be reviewed.

4.3.6 Inspection history of the UST system shall be evaluated.

4.4 On-Site Testing

4.4.1 All test methods shall be in accordance with applicable engineering standards. See NACE Standard TM0101.

4.4.2 Soil borings may be performed. The following measurements should be recorded as each test hole boring progresses:

(a) structure-to-soil potential profile; and

(b) soil resistivity profile.

4.4.3 When required, soil samples should be extracted from the bore holes and placed in sealed sample containers for analysis to include:

(a) resistivity;

(b) pH;

(c) sulfide ion concentration;

(d) chloride ion concentration;

(e) moisture content; and

(f) presence of disruptive bacteria, such as sulfate-reducing bacteria (SRB).

4.4.4 Tests that should be included in the investigation for the evaluation of corrosion on UST systems and the design of CP systems include the following:

4.4.4.1 Soil Resistivity: Low-resistivity soils are usually more corrosive than high-resistivity soils; however, serious corrosion can also be associated with high-resistivity soils, particularly when the soil composition is not uniform. Variations in resistivity indicate variations in soil composition, which is conducive to galvanic corrosion. Accepted soil resistivity tests include the Wenner four-pin, soil box, and single-probe methods.[9]

(3) American Petroleum Institute (API), 1220 L St. NW, Washington, DC 20005-4070.
(4) ASTM International (ASTM), 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959.

4.4.4.2 Structure-to-Soil Potential

4.4.4.2.1 Structure-to-soil potentials are used to evaluate the corrosion activity associated with UST systems. If properly interpreted and correlated with other measurements, structure-to-soil potentials should give an indication of the severity of both galvanic and stray-current corrosion cells.

4.4.4.2.2 Measurements should be taken with a high-input impedance voltmeter.

4.4.4.2.3 Saturated copper/copper sulfate reference electrodes (CSE) are used for underground corrosion testing because they are stable, rugged, and yield reproducible results. Electrode placement is important when the data are collected. Reference electrode location for each potential measurement shall be properly noted. When test borings are made, the reference electrode should be placed near the structure/soil interface. Typically, the test hole is drilled 0.3 m (1 ft) from the edge of the UST to a depth of 0.6 m (2 ft) below the UST. Structure-to-soil potentials are recorded at various depths to establish the potential profile from grade level to below the UST.

4.4.4.3 Stray current can emanate from the operation of direct current (DC) transit systems, CP rectifiers, DC welding equipment, and DC motors. When discharged from the surface of a steel structure, stray current consumes approximately 9 kg/A·y (20 lb/A·y) of metal. Concentrated stray-current corrosion can cause rapid deterioration of UST systems. The presence of stray current is detected through the use of structure-to-soil potential, current flow, and potential gradient measurements.

4.4.4.4 Current requirement: Tests simulating the effects of a permanently installed CP system can be evaluated to determine the DC requirements for CP. Temporary CP anodes shall be installed in the surrounding soil and connected to the positive terminal of a DC power source; the negative terminal of the power source shall be connected to the UST system under test. When using this method, it is not safe to create a connection to a structure in a vapor-rich environment. Connections should not be made inside the UST above the fuel level. Structure-to-soil potentials shall then be measured at accessible locations. Data, including the polarization effects over time, can then be extrapolated to determine the requirements for CP current. The status of electrical isolation of the structure under study should be considered in the evaluation of current requirements testing.

4.4.4.5 Electrical continuity testing shall be performed to determine whether all USTs and piping are electrically continuous and whether continuity with other structures exists. Temporary anodes shall be energized by a DC power source that is cycled on and off. A CSE or other suitable reference electrode (e.g., calomel, silver/silver chloride, zinc) shall be placed in a stationary position, and structure-to-soil potentials recorded with the structure connection moved from one location to the next. At each point of structure connection, both on and instant-off potential measurements can be observed with the cycling of the DC power source. The reference electrode must remain at the same location for the duration of each continuity test. Electrical continuity is indicated when the potential measurements and changes in potential measurements with the applied current are approximately equal, regardless of the point of connection to the structure. Differences in the structure-to-soil potentials and changes in potential indicate the lack of electrical continuity between the points of contact.

4.5 Laboratory Testing

4.5.1 pH: For a given resistivity, acid soils (pH less than 7) are more conducive to ferrous corrosion. At pH values less than 4, the rate of corrosion accelerates rapidly. At pH values greater than 10, the environment tends to passivate the steel. All pH testing should be done in accordance with ASTM G51.[10]

4.5.2 Chloride Ion: Chloride ions are depassivating agents and cause pitting corrosion. ASTM D512[11] is used to measure chloride ion concentration.

4.5.3 Sulfide Ion and SRB: The presence of sulfide ions in the soil indicates anaerobic conditions and the presence of SRB. Under these conditions, SRB can greatly accelerate the rate of corrosion. The test procedure used to detect sulfide ions shall satisfy the requirements of Standard Method 4500-S^{2-}.[12] The test procedure for SRB shall satisfy the requirements of Standard Method 9240,[13] Section D, “Bacteria Living in Acidic Environments.”

4.5.4 Moisture Content

4.5.4.1 The moisture content is a significant parameter in determining the corrosiveness of a soil environment. When soil samples are collected, they shall be immediately sealed in sample containers to prevent evaporation and contamination. The moisture content of the samples should be determined using ASTM D2216.[14]

4.5.4.2 Test borings allow for a determination of the variations in moisture content with depth. When encountered, the depth of the water table should also be noted on the boring logs.

4.6 Data Analysis

This paragraph outlines the analysis that may be performed prior to designing a CP system to protect existing UST systems.

4.6.1 The results of tests determine the extent and type of CP system to be installed. The analysis of these data is valuable in determining unusual conditions (e.g., stray current, dissimilar metals, and large corrosion cells), native-state characteristics needed for commissioning the completed CP system, and electrical continuity.

4.6.2 Results of other tests (soil resistivity, structure-to-soil potential, stray current, current requirements, electrical continuity, pH, chloride ion, sulfide ion, moisture, bacteria, etc.) aid in determining the type and extent of the CP system to be considered. Interpretation of these results should consider seasonal variations.

4.6.3 Investigation of all previous repairs to the UST system shall be performed to determine the probability of severe corrosion damage to these facilities. All necessary repairs shall be completed before the installation of a CP system is considered (see API Std 1631 for additional information).

4.6.4 All UST systems may not be good candidates for a CP system. If inspection tests reveal critically damaged components, consideration should be given to UST system replacement or removal from service.

Section 5: Criteria for Cathodic Protection

This section lists criteria for CP which, when complied with either separately or collectively, indicate that adequate CP of a metallic UST system has been achieved.

5.1 General

5.1.1 The objective of using CP is to control external corrosion of metallic UST systems.

5.1.2 The selection of a particular criterion depends, in part, on prior experience with similar structures and environments in which the criterion has been used successfully.

5.1.3 The criteria in Paragraph 5.2 were developed through laboratory experiments or were determined empirically by evaluating data obtained from successfully operated CP systems. It is not intended that people responsible for corrosion control be limited to these criteria if it can be demonstrated by other means that the control of corrosion has been achieved.

5.1.4 Potential measurements on UST systems should be made with the reference electrode located on the electrolyte surface as close as possible to the UST system. Consideration must be given to voltage (IR) drops other than those across the structure/electrolyte boundary, the presence of dissimilar metals, and the influence of other structures that may interfere with valid interpretation of potential measurements. All potential measurements shall be taken with reference electrodes that are in contact with the electrolyte. Potential measurements shall not be taken through concrete or asphalt. Soil contact may be established through at-grade openings, by drilling a small hole in the concrete or asphalt, or by contacting a seam of soil between concrete and asphalt.

NOTE: Consideration is understood to mean the application of sound engineering practice in determining the significance of voltage drops. The primary method for considering voltage drops in an impressed current and field-installed galvanic anode system shall be by taking instant-off potential measurements. See NACE Standard TM0101 for details on how to use this test method. Other methods, such as the following, may also be used:

(a) Measuring or calculating the voltage drop(s);

(b) Reviewing the historical performance of the CP system;

(c) Evaluating the physical and electrical characteristics of the UST system and its environment; or

(d) Determining whether or not there is physical evidence of corrosion.

5.2 Criteria for Steel Structures

5.2.1 Corrosion control can be achieved at various levels of cathodic polarization depending on the environmental conditions. However, in the absence of data that demonstrate that adequate CP has been achieved, one or more of the following shall apply:

5.2.1.1 A negative (cathodic) potential of at least 850 mV with the CP applied. This potential is measured with respect to a CSE contacting the electrolyte. Voltage drops other than those across the structure/electrolyte boundary must be considered for valid interpretation of this potential measurement.

5.2.1.2 A negative polarized potential (see definition in Section 2) of at least 850 mV relative to a CSE.

5.2.1.3 A minimum of 100 mV of cathodic polarization. The formation or decay of polarization may be used to satisfy this criterion.

5.2.2 Interruptible CP coupons may be installed for the purpose of determining the true level of cathodic polarization. See NACE Standard TM0101 for more information.

5.3 Alternative Reference Electrodes

Other standard reference electrodes may be substituted for the CSE. However, their potential measurements must be converted to the CSE equivalents as shown in Table 1.

Table 1
Conversion of Other Potential Measurements to CSE Equivalents

Reference Electrode	Equivalent to –850 mV CSE	Correction
Calomel	**–776 mV**	Add **–74 mV**
Silver/Silver Chloride	**–780 mV**	Add **–70 mV**
Zinc	**+250 mV**	Add **–1,100 mV**

5.4 Special Considerations

5.4.1 Special cases, such as those involving stray currents and stray electrical gradients, that require the use of criteria different from those listed above, may exist. Measurements for current loss and gain on the structure have been useful in such cases.

5.4.2 Abnormal conditions in which protection is ineffective or only partially effective sometimes exist. Such conditions may include elevated temperatures, disbonded coatings, shielding, bacterial attack, and unusual contaminants in the electrolyte.

5.4.3 When structures that have dissimilar metals are protected, a negative structure-to-soil potential equal to that for protection of the most anodic metal should be maintained.

Section 6: Cathodic Protection System Design

6.1 General

6.1.1 Information regarding the design of impressed current and galvanic anode CP systems can be found in NACE SP0169[15] and in this standard.

6.1.2 Information useful in the CP system design includes:

(a) site plan and UST system layout;

(b) pipe, fittings, and other appurtenances;

(c) pumps and power supplies;

(d) existing and proposed CP systems;

(e) nearby buried metallic structures;

(f) site accessibility;

(g) soil conditions (e.g., resistivity, chemical composition, aeration, and moisture);

(h) electrical isolation;

(i) coating integrity;

(j) elevated temperatures;

(k) shielding;

(l) treated UST backfill material;

(m) dissimilar metals;

(n) concrete/metal interfaces; and

(o) complexing agents.

6.2 Galvanic Anode Systems

This paragraph describes the factors that should be considered in the design of a CP system for existing UST systems using galvanic anodes.

6.2.1 Galvanic anode CP systems may be applied to UST systems when the metallic surface area exposed to the soil is minimized through the application of a dielectric coating or when the surface area is small because of UST size. When current requirements are high, the use of an impressed current system should be considered to minimize the cost of the CP system (see Paragraph 6.3).

6.2.2 Electrical Isolation

6.2.2.1 Electrical isolation methods should be used to isolate the primary UST from other electrically grounded systems.

6.2.2.2 All uncoated associated piping can be electrically isolated from the UST. Submersible pumps can be isolated from the metallic piping and UST by the use of dielectric isolating unions and bushings.

6.2.2.3 Electrical isolation of the piping can be accomplished by the use of flange isolation kits, dielectric bushings, or dielectric unions rated for the proper operating pressure and compatible with the product being stored in the UST. Use of dielectric unions underground should be avoided whenever possible. Dielectric unions should remain exposed for future inspection and maintenance.

6.2.2.4 When required by local codes and regulations, the UST shall be grounded to protect against damage caused by lightning. This must be accomplished without compromising the CP design.

6.2.3 Galvanic Anode Selection

6.2.3.1 The three most common types of galvanic anodes that are effective in soil environments are standard-potential magnesium (ASTM B843,[16] UNS[(5)] M11632), high-potential magnesium (ASTM B843, UNS M15102), and high-purity zinc (ASTM B418,[17] UNS Z13000). The selection and use of these anodes are based on the current requirements for the structure to be protected, the soil conditions, and the temperature of the structure to be protected.

6.2.3.2 The current output from each type of anode depends greatly on the soil conditions, the anode shape, and the driving potential of the anode.

[(5)] Unified Numbering System for Metals and Alloys (UNS). UNS numbers are listed in *Metals & Alloys in the Unified Numbering System*, latest revision (Warrendale, PA: SAE International and West Conshohocken, PA: ASTM International).

6.2.3.3 When high-purity zinc anodes are used, care shall be exercised to ensure the anodes meet the requirements of ASTM B418, Type II anode material. The purity of the zinc greatly affects its performance as a galvanic anode for soil applications.

6.2.3.4 Zinc anodes shall not be used when the temperature of the anode environment is greater than 49 °C (120 °F). The high temperature can cause the anode to assume passive characteristics. The presence of some chemicals in the soil, such as carbonates, bicarbonates, and nitrates, may also affect the performance of bare zinc as an anode material.

6.2.3.5 Galvanic anode performance is enhanced with special backfill material. A mixture of 75% gypsum, 20% bentonite, and 5% sodium sulfate is typically used with magnesium anodes. Either 75% gypsum, 20% bentonite, and 5% sodium sulfate or a mixture of 50% gypsum and 50% bentonite may be used with zinc anodes.

6.2.3.6 The galvanic anodes should be supplied with adequate lead wire attached. Lead wire shall be at least 4 mm^2 (#12 American Wire Gauge [AWG]) solid wire with thermoplastic-insulated wire (TW) or equivalent oil- and water-resistant insulation.

6.2.4 Galvanic Anode Installation

6.2.4.1 The galvanic anodes shall be installed around the UST in a manner that allows optimal current distribution. Anodes should be placed close to or below the elevation of the bottom of the UST. If multiple UST installations are spaced closely together, installation of additional anodes between the USTs and above the centerline of the USTs may be required to provide adequate current distribution to the upper surfaces of the UST.

6.2.4.2 The galvanic anode lead wires shall be installed with sufficient slack to avoid possible damage caused by settlement of surrounding soil.

6.3 Impressed Current Systems

This paragraph describes the factors considered when designing impressed current CP systems.

6.3.1 In the design of an impressed current CP system, the following factors shall be considered:

(a) recognition of hazardous conditions prevailing at the site and selection and specification of materials and installation practices that ensure safe installation and operation;

(b) all applicable regulatory codes;

(c) selection and specification of materials and installation practices that ensure dependable, economical operation of the CP system throughout its intended operating life; and

(d) selection of proposed installation to minimize stray currents.

6.3.2 Electrical Continuity

6.3.2.1 All structures to be cathodically protected must be electrically continuous. Bonds may be required between piping and USTs and, in some cases, from UST to UST. Electrical conduits, hydraulic lifts, and utility piping, such as water and gas piping, must be investigated for electrical isolation or continuity in accordance with NACE Standard TM0101.

6.3.2.2 Nonwelded joints may not be electrically continuous. Electrical continuity between all components of the cathodically protected UST system must be verified.

6.3.3 Impressed Current Anode Systems

6.3.3.1 Impressed current CP systems shall be designed to mitigate any adverse effects from stray current on foreign metallic structures within the influence of the CP system.

6.3.3.2 A variety of materials such as (a) high-silicon cast iron, (b) graphite, (c) mixed-metal-oxide-coated titanium, and (d) platinum-coated titanium or niobium are used for impressed current anodes. These impressed current anodes are normally installed with low-resistivity carbonaceous backfill.

6.3.3.3 Impressed current anode lead wires shall be constructed with insulation that meets the mechanical and chemical resistance requirements of the environment. Impressed current anodes shall be connected either singularly or in groups to the positive terminal of a DC source. The cathodically protected UST system components shall be connected to the negative terminal with insulated cable.

6.3.3.4 Cables between anodes, rectifiers, and negative returns from the structures to the rectifier require special insulation. Underground splices should be avoided. Cables should be installed in plastic conduit. If installed in soil, cable insulation shall have the following qualities:

(a) abrasion resistance;

(b) low moisture absorption; and

(c) resistance to UST product spills.

6.3.3.5 The life of impressed current anodes can be extended by the use of low-resistivity, carbonaceous, conductive backfill around the anodes. The most common of these backfill materials are metallurgical coke breeze made from coal and calcined petroleum coke. Low-resistivity, carbonaceous, conductive backfill also reduces the anode-to-earth resistance.

6.3.3.6 Impressed current anode groundbed configurations may be vertical, horizontal, or angle drilled. The selection of anode configuration is dependent on environmental factors, current requirements, current distribution, and the size and type of structure to be cathodically protected. Caution should be exercised to ensure that impressed current anode placement results in uniform distribution of CP current to the cathodically protected UST system surfaces.

6.3.3.7 The current requirement for achieving a given CP criterion may be determined by preliminary testing on existing structures through the use of temporary or simulated CP systems. The current requirement may be estimated by calculating surface areas and applying a minimum protective current density based on experience and sound engineering judgment.

6.3.3.8 Although there are many sources of DC for impressed current CP, rectifiers are most commonly used. Various types of rectifiers such as (a) fixed voltage; (b) constant current; (c) automatic potential control; and (d) combinations of these are available.

6.3.3.9 Separate terminal boxes with the DC power supply that can accommodate multiple circuit outputs that can be varied to individual circuits or anodes are available. These come equipped with shunts so that individual anode current outputs can be monitored.

6.3.3.10 All impressed current CP systems shall be designed with safety consideration as a priority. Caution should be exercised to ensure that all cables are protected from physical damage and from the possibility of arcing. When required, rectifiers and junction boxes shall be explosion proof.

6.4 Test Stations

6.4.1 Test stations for potential and current measurements should be considered for each CP system at sufficient locations to facilitate CP testing.

6.4.2 Test stations have a number of different configurations, including the following:

6.4.2.1 The test station may be cast iron or impact-resistant plastic but shall be set at grade in a manner to ensure its long-term durability. The test station may contain a terminal block. Wires should be color coded or otherwise permanently identified. Wire shall be installed with slack. Damage to insulation shall be avoided, and proper repairs must be made if damage occurs.

6.4.2.2 A test station may consist of a test lead continuous with the structure surface, secured by a nonconductive strap to a fixture, and accessible in the manhole opening.

6.4.2.3 If a portable reference electrode is used for monitoring, then an area of clean, unshielded backfill or soil should be made accessible in the manhole area for electrode placement.

6.4.3 Provisions should be made to monitor potentials at the bottom of USTs. Such facilities may include:

(a) permanent reference electrodes; and

(b) portable reference electrodes inserted in access tubes.

6.4.4 For galvanic anode CP systems, the test station design shall permit disconnection of the galvanic anodes to correct potential measurements for voltage drop to evaluate the protection level. When desired, the test station should also accommodate test leads from buried reference electrodes.

6.4.5 The test station should be clearly marked, accessible, and installed so that it is protected from vehicular traffic.

6.4.6 All lead wires to the test station shall be protected from damage by either a minimum 0.5 m (18 in) burial depth or a nonmetallic conduit.

6.5 Wire and Connections

6.5.1 Wire used for anode, reference electrode, and monitoring connections requires insulation with the following qualities:

(a) low moisture absorption;

(b) resistance to UST product spills;

(c) abrasion resistance; and

(d) sufficient breaking strength for the application.

6.5.2 Anode lead wires shall have the wire/anode interface connection secured by soldering or brazing. Weld-on anodes shall have a weldable steel core for connection directly to the structure. Wiring attached to the structure should be connected by exothermic weld, weldable steel pressure wire connectors, or appropriate mechanical connectors, and should be able to withstand a pull test in accordance with ASTM F458.[18] The area of the connection shall be cleaned by scraping or brushing prior to attachment. The connector and connection area shall be thoroughly coated after attachment.

6.6 Miscellaneous

6.6.1 Design Drawings and Specifications

6.6.1.1 Drawings shall be prepared to show the overall layout of the UST system structures to be cathodically protected, the CP system, and associated appurtenances.

6.6.1.2 Specifications shall be prepared for all materials and installation practices that are used in construction of the CP system.

6.6.2 Spill protection, overfill protection, release detection, vapor recovery measures, and electrical grounding or internal linings should be considered in the design of the CP system for the UST system.

Section 7: Installation of Cathodic Protection Systems

7.1 General

7.1.1 All work shall be performed in accordance with all applicable health and safety regulations.

7.1.2 Notifications

7.1.2.1 Coordinating committees in the area (such as Underground Corrosion Control Coordinating Committees [UCCCs][(6)]) and utility operators should be notified prior to construction and installation of the CP system(s).

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(6) The NACE International Technical Activities Division may be contacted to determine whether a UCCC is registered in the area; Call +1 281-228-6200, or e-mail tcc@nace.org.

7.1.2.2 Prior to excavation, public or private utility owners, as well as owners of other underground structures in the immediate vicinity, shall be notified. This provides the owners of underground structures with time to locate any structures within the proposed construction zone to avoid accidental physical damage.

7.2 Site Conditions

7.2.1 Pertinent as-built construction drawings from the UST system installation shall be reviewed prior to construction. Although the location of most USTs can be determined, the location of product piping, vapor recovery lines, and vent lines can be difficult to determine. The underground structures at the facility include not only the USTs and associated piping, but also the monitoring wells and sensors, tank pit liners, and utilities that may be present.

7.2.2 Prior to installation of the CP system, certain factors such as water table, vehicular and pedestrian traffic, and aboveground structures shall be considered.

7.3 Installation Procedures

7.3.1 Although most installations do not normally disrupt operations, installation shall be coordinated with appropriate operations personnel to minimize any disruption of services. This work should also be coordinated with any other construction at the facility.

7.3.2 All construction work performed on CP systems shall be done in accordance with construction drawings and specifications. All deviations from construction specifications shall be approved prior to installation and shall be noted on as-built drawings.

7.3.3 The installation of CP systems shall be under the supervision of trained and qualified personnel to ensure that the installation is done in accordance with the drawings and specifications.

7.3.4 Galvanic Anodes

7.3.4.1 Packaged galvanic anodes should be kept dry during storage. Electrical continuity between anode and lead wire shall be tested without compromising the integrity of the anode/backfill package. Any waterproof covering must be removed before installation.

7.3.4.2 Galvanic anodes shall be installed according to the CP system specifications. Packaged galvanic anodes shall be surrounded with special backfill and compacted. Paragraph 6.2.3.5 describes the special backfill material. Also see Paragraph 3.6.1.

7.3.4.3 Care should be exercised so that lead wires and connections are not damaged during backfilling operations. Lead wires should have enough slack to prevent strain. Galvanic anodes should not be carried or lowered into the excavation by the lead wire.

7.3.5 Impressed Current Anodes

7.3.5.1 Impressed current anodes shall be inspected for defects and for conformance to specified material. Care shall be exercised to avoid damaging the anodes during handling and installation.

7.3.5.2 Impressed current anodes shall be buried as indicated in construction specifications. Backfill material shall be placed to ensure there are no voids around anodes. Backfilling operations shall not damage the anode or its lead wire.

7.3.5.3 Impressed current anode lead wires shall be carefully inspected for insulation defects. Extreme care shall be taken to avoid damaging the wire insulation. Anodes with damaged lead wire insulation shall not be installed.

7.3.6 Wire and Cable

7.3.6.1 Care shall be exercised when direct burial cable is installed to the anode sites to avoid damage to insulation. Sufficient slack shall be left to avoid strain. Backfill material around the cable shall be free of rocks and foreign matter that might damage the wire insulation when the wire is installed in a trench.

7.3.6.2 Underground splices of header cable to the groundbed should be avoided. Connections between header cable and conductors from anodes shall be mechanically secure and electrically conductive. If buried or submerged, all splices and connections must be sealed to prevent moisture penetration and protect the connection from the environment.

7.3.7 Rectifier Units

7.3.7.1 The rectifier unit shall be inspected to ensure that internal connections are mechanically secure and that no damage is present. Rating of the DC power source shall comply with construction specifications.

7.3.7.2 Cable connections to the rectifier shall be mechanically secure and electrically conductive. Before the power source is energized, it shall be verified that the negative cable is connected to the structure to be cathodically protected and that the positive cable is connected to the anodes. After the DC power source has been energized, measurements shall be made to verify that these connections are correct.

7.3.7.3 Alternating current (AC) wiring to rectifiers shall comply with local and national electrical codes and requirements of the utility supplying power. A disconnect switch external to the rectifier should be provided on a dedicated AC circuit. The rectifier case shall be properly grounded.

7.3.8 Wire Connections

7.3.8.1 The structure and all wires shall be clean, dry, and free of foreign materials when the connections are made. Connections of wires to the structure shall be installed so that they will remain secure and electrically conductive.

7.3.8.2 All wire attachments should be coated with an electrical isolating material. If the structure is coated, the isolating material shall be compatible with the coating and wire insulation.

7.3.8.3 Wire shall be installed with slack. Damage to insulation shall be avoided.

7.3.9 Electrical Isolation Devices

Inspection and electrical measurements shall be made to ensure that electrical isolation devices are effective.

7.4 Cathodic Protection System Commissioning

7.4.1 The energizing of CP systems for UST systems shall be based on the initial CP system design parameters. Major items that should be known are:

(a) CP system design criteria;

(b) locations of CP equipment;

(c) types of test facilities;

(d) types of CP installed;

(e) proximity of foreign structures; and

(f) safety hazards.

7.4.2 Prior to the energizing of any impressed current CP system, notification shall be given to operators of nearby utilities and pipelines.

7.4.3 Prior to the energizing of the CP system, data and information shall be collected to provide initial baseline data for items such as:

(a) structure-to-soil potentials of the UST;

(b) structure-to-soil potentials of all associated metallic piping;

(c) electrical isolation, if present;

(d) structure-to-soil potentials of foreign structures;

(e) CP coupons, if present; and

(f) permanent reference electrodes, if present.

7.4.4 Verification of the following details regarding CP devices and hardware shall be made prior to energizing of the CP system:

(a) location of anodes;

(b) ratings of impressed current sources;

(c) location of test facilities; and

(d) location of CP system negative cables and connection points.

7.4.5 All initial baseline CP data shall be documented and the records maintained for the life of the UST system. Any deviations from the CP system design or as-built documentation shall be noted and included with the initial baseline CP data.

7.4.6 Current Adjustment

7.4.6.1 The exact operating level of the CP system shall be determined by a series of tests at various operating levels. The specific operating level depends on the criterion for CP used for the UST system (see Section 5).

7.4.6.2 When the operating levels of the CP system are adjusted, stray current effects on adjacent structures such as the following should be considered:

(a) piping separated from the UST(s) or high-resistance fittings (e.g., threaded joints);

(b) buried electric facilities;

(c) buried fire protection piping;

(d) buried water piping;

(e) other adjacent tank systems; and

(f) municipal or utility structures in close proximity to the facility at which the UST(s) is (are) located.

7.4.7 Testing

7.4.7.1 The final operating level of the CP system shall be established to achieve the appropriate CP criterion (see Section 5).

7.4.7.2 Documentation of all operating parameters, such as initial baseline data, as-built drawings, operating currents, locations of test facilities, key monitoring locations, equipment manuals, and groundwater level, shall be performed after the CP system is energized.

7.4.7.3 All appropriate electrical parameters shall be recorded and documented for future reference.

7.5 Records

7.5.1 UST system information shall include the following:

(a) dimension and capacity;

(b) layout of pipe system;

(c) date of installation;

(d) type of excavation and installation details;

(e) history of UST system performance and repairs;

(f) history of previous corrosion control system and performance; and

(g) stored product.

7.5.2 Complete information about the design and installation of CP system shall include:

(a) power source capacity;

(b) number and location of anodes;

(c) anode material and design life;

(d) anode installation details;

(e) type, quantity, and location of permanent reference electrodes;

(f) date of energizing and initial current and voltage;

(g) structure-to-soil potential measurements;

(h) results of continuity testing for all components listed in Paragraph 6.3.2;

(i) approved as-built drawings for final CP system design; and

(j) approved final commissioning report.

Section 8: Operation and Maintenance

This section presents standard practices for maintaining continuous, effective, and efficient operation of CP systems for UST systems.

8.1 General

8.1.1 Electrical measurements and inspection should be performed to determine that CP has been established according to applicable criteria and that each part of the CP system is operating properly.

8.1.2 Conditions that affect CP are subject to change with time. Corresponding changes may be required in the CP system to maintain protection.

8.1.3 Periodic measurements and inspections should be performed to detect changes in the CP system. Conditions in which operating experience indicates testing and inspections should be performed more frequently than set forth in this standard may exist. See NACE Standard TM0101 for more information.

8.1.4 Care shall be exercised in selecting the location, number, and type of electrical measurements used to determine the adequacy of CP.

8.2 Maintenance Surveys

8.2.1 A potential survey shall be performed after each CP system is energized to determine whether it satisfies applicable criteria (see Section 5) and operates efficiently (see Paragraph 7.4).

8.2.2 Monitoring

8.2.2.1 All CP systems shall be monitored in accordance with NACE Standard TM0101 to ensure effective operation as designed. The CP system shall be tested to verify its effectiveness after installation and whenever construction or maintenance in the area of the UST system occurs.

8.2.2.2 Field-installed galvanic and impressed current CP systems shall be tested annually.

8.2.2.3 A factory-installed CP system shall be tested at an interval not to exceed three years if manufactured in accordance with a nationally recognized standard or code.

8.2.3 Inspection, potential surveys, and tests of CP systems shall be made to ensure their effectiveness and proper operation and maintenance as follows:

8.2.3.1 All sources of impressed current shall be checked at intervals not exceeding two months. Evidence of proper functioning may be current output, normal power consumption, or a signal indicating normal operation.

8.2.3.2 All impressed current CP systems shall be inspected annually as part of a preventive maintenance program to minimize in-service failure. Inspections should include a check for electrical shorts, ground connections, meter accuracy, efficiency, circuit resistance, rectifier output voltage, rectifier output current, and whenever possible, individual anode current output. The effectiveness of electrical isolation devices and continuity bonds should be evaluated during the periodic surveys. This may be accomplished by on-site inspection or by evaluating corrosion test data.

8.2.4 Test equipment used for obtaining each electrical value shall be of an appropriate type (see Paragraph 4.4.4). Instruments and related equipment shall be maintained in good operating condition and checked annually for accuracy.

8.3 Visual Inspection

If the UST or any part of the UST system is uncovered, visual inspection for evidence of corrosion and coating deterioration should be made. The necessary repairs should be implemented to ensure continued corrosion protection of the UST system.

8.4 Remedial measures shall be taken when periodic tests and inspections indicate that CP is no longer adequate according to applicable criteria for CP (see Section 5). These measures may include the following:

8.4.1 Repair, replacement, or adjustment of CP system components;

8.4.2 Providing supplementary facilities when additional CP is necessary;

8.4.3 Repair, replacement, or adjustment of continuity and interference bonds;

8.4.4 Elimination of accidental metallic contact; and

8.4.5 Repair of defective electrical isolation devices.

8.5 Records

All records of the CP system shall be maintained by the owner for the life of the UST system, including the following.

8.5.1 A record of potential surveys, inspections, and tests shall be maintained to demonstrate that applicable criteria for CP have been satisfied (see Section 5).

8.5.2 A record of the maintenance performed on the CP system shall be recorded, including repair and replacement of the following:

8.5.2.1 Rectifiers and other DC power sources;

8.5.2.2 Anodes, connections, and cables.

8.5.2.3 Coatings;

8.5.2.4 Electrical isolation devices; and

8.5.2.5 Test leads, and other test facilities.

8.5.3 Records sufficient to demonstrate the evaluation of the need for and the effectiveness of the CP system should be retained as long as the UST system involved remains in service. Other related corrosion control records should be retained for a period that satisfies individual company needs.

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[(8)] American Water Works Association (AWWA), 6666 W. Quincy Ave., Denver, CO 80235.
[(9)] Water Environment Federation (WEF), 601 Wythe St., Alexandria, VA 22314.

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