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USACE / NAVFAC / AFCEC / NASA **UFGS-26 42 15 (May 2021)**

Preparing Activity: USACE

Superseding
UFGS-26 42 15.00 10 (February 2013)
UFGS-26 42 22.00 20 (January 2008)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2021
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DIVISION 26 - ELECTRICAL

SECTION 26 42 15

CATHODIC PROTECTION SYSTEM FOR THE INTERIOR OF STEEL WATER TANKS

05/21

PART 2 PRODUCTS

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SECTION 26 42 15

CATHODIC PROTECTION SYSTEM FOR THE INTERIOR OF STEEL WATER TANKS
05/21

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NOTE: This guide specification covers the requirements for steel water tank cathodic protection systems using either galvanic or impressed current systems (impressed current or galvanic anodes).

Adhere to UFC 1-300-02 **Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable item(s) or insert appropriate information.**

Remove information and requirements not required in respective project, whether or not brackets are present.

Comments, suggestions and recommended changes for this guide specification are welcome and must be submitted as a Criteria Change Request (CCR)**.**
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NOTE: Each Service has a specialized facilities engineering activity: Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) for the Navy and Marine Corps, Engineering Research and Development Center (ERDC) for the Army, and Air Force Civil Engineering Corps (AFCEC) for the Air Force, has significant experience and technical expertise in the area of field testing and commissioning of new systems. If Reach-Back support is required, the technical representative (electrical engineer) editing this document for a specific project must contact the NAVFAC EXWC Design and Construction Department" and the relevant ERDC

and AFCEC departments for consultation during the design stage of the project and include the bracketed option in the 'Submittals' section.
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NOTE: One of the major factors influencing selection of the type of cathodic protection system is the resistivity of the water involved. When the water resistivity is higher than 10,000 ohm-cm, impressed current systems are usually used. Other considerations include availability of electric power and the costs of installation, operation and maintenance. Where relatively large currents are required and reasonable access to power is available, the impressed current system will generally be found to be more economical. The requirements for the cathodic protection systems should be determined by a corrosion engineer following the criteria, design, and installation recommendations included in the National Association of Corrosion Engineers Standard; SP-0388, "Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Tanks", and SP0-196, "Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks".
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NOTE: The following information must be shown on the drawings:

1. Dimensions of tank, including riser (if tank is elevated), structural supports and overflow.

2. Locations of all equipment, including anodes, reference electrodes, junction boxes, test boxes, rectifiers, power connections (with branch circuit source), wire conduit, and remote monitoring equipment.

3. Installation details for anodes, test stations and rectifiers.

4. Electrical single-line diagrams, elevations, limiting dimensions, and equipment ratings which are not covered in the specification.

4. Single-line diagrams elevations, limiting dimensions, and equipment ratings which are not covered in the specification.

5. Remote indicating or control requirements.

6. Grounding (riser diagrams).
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PART 1   GENERAL

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NOTE: The requirements for the cathodic protection systems must be determined by a corrosion engineer following the criteria, design, and installation recommendations included in the National Association of Corrosion Engineers (NACE) Standard Practice NACE SP0388(2018) Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks, NACE SP0196,(2015) Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks, and others listed in the specification.
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NOTE: The following information must be on the drawings:

1. Installation details for anodes and test stations.

2. Location of equipment.

3. Single-line diagrams elevations, limiting dimensions, and equipment ratings which are not covered in the specification.

4. Remote indicating or control requirements.

5. Grounding.
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1.1   REFERENCES

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NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a Reference Identifier (RID) outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME B1.1	(2003; R 2018) Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B18.2.1	(2012; Errata 2013) Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	(2015) Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA D104	(2011) Automatically Controlled, Impressed-Current Cathodic Protection for the Interior Submerged Surfaces of Steel Water Storage Tanks

ASTM INTERNATIONAL (ASTM)

ASTM A194/A194M	(2020a) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A307	(2021) Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
ASTM A518/A518M	(1999; R 2018) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
ASTM B3	(2013) Standard Specification for Soft or Annealed Copper Wire
ASTM B8	(2011; R 2017) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B418	(2016a; R2021) Standard Specification for Cast and Wrought Galvanic Zinc Anodes
ASTM B843	(2018) Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
ASTM C94/C94M	(2021a) Standard Specification for Ready-Mixed Concrete
ASTM D709	(2017) Standard Specification for Laminated Thermosetting Materials
ASTM D1248	(2016) Standard Specification for Polyethylene Plastics Extrusion Materials

	for Wire and Cable
ASTM D2028/D2028M	(2015) Cutback Asphalt (Rapid-Curing Type)
ASTM D3381/D3381M	(2018) Standard Specification for Viscosity-Graded Asphalt Binder for Use in Pavement Construction
ASTM F1182	(2007; R 2019) Anodes, Sacrificial Zinc Alloy

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE C2	(2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code
IEEE C135.30	(1988) Standard for Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

NACE INTERNATIONAL (NACE)

NACE SP0188	(1999; R 2006) Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
NACE SP0193	(2016) Application of Cathodic Protection to Control External Corrosion of Carbon Steel On-Grade Storage Tank Bottoms
NACE SP0196	(2020) Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks
NACE SP0388	(2018) Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks - Item No. 21040

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C119.1	(2016) Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600 Volts
NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures
NEMA RN 1	(2005; R 2013) Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
NEMA ST 1	(1988; R 1994; R 1997) Specialty

Transformers (Except General Purpose Type)

NEMA TC 2	(2020) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code

NSF INTERNATIONAL (NSF)

NSF/ANSI 61	(2020) Drinking Water System Components - Health Effects

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-A-18001	(1993) Anodes, Sacrificial Zinc Alloy
MIL-I-1361	(1985; Rev C; Notice 1 1991; Notice 2 2021) Instrument Auxiliaries, Electrical Measuring: Shunts, Resistors and Transformers

UNDERWRITERS LABORATORIES (UL)

UL 6	(2007; Reprint Sep 2019) UL Standard for Safety Electrical Rigid Metal Conduit-Steel
UL 44	(2018; Reprint May 2021) UL Standard for Safety Thermoset-Insulated Wires and Cables
UL 83	(2017; Reprint Mar 2020) UL Standard for Safety Thermoplastic-Insulated Wires and Cables
UL 467	(2013; Reprint Jun 2017) UL Standard for Safety Grounding and Bonding Equipment
UL 486A-486B	(2018; Reprint May 2021) UL Standard for Safety Wire Connectors
UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 506	(2017) UL Standard for Safety Specialty Transformers
UL 510	(2020) UL Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013; Reprint Aug 2017) UL Standard for Safety Metallic Outlet Boxes
UL 514B	(2012; Reprint May 2020) Conduit, Tubing and Cable Fittings

1.2 DEFINITIONS

It is convenient to classify corrosion by the forms in which it manifests itself, the basis for this classification being the appearance of the corroded metal. Each form can be identified by visual observation, although, in some cases, magnification is required. Valuable information for the solution of a corrosion problem can often be obtained through careful observation of the corroded test specimens or failed equipment. Examination before cleaning is particularly desirable. Cathodic Protection is a method used to control corrosion.

1.2.1 Cathodic Protection

Cathodic Protection (CP) is an electrochemical (half electrical and half chemical) method used to control corrosion of buried or submerged metallic structures. It prevents corrosion by making the protected structure a cathode by installing a more anodic metal (sacrificial or galvanic) anode or a metallic (impressed current) anode connected to a Direct Current (DC) power source. When the proper amount of current is applied to the structure, it becomes a cathode. Since all corrosion occurs at the anode, the structure no longer corrodes. The electrons move in the metallic path (electrical). Reduction (chemical) reactions occur at the surface of the cathode resulting in a hydrogen coating and more alkaline environment. Oxidation (chemical) reactions occur at the surface of the anode resulting in corrosion and a more acidic environment. After a CP system is installed and adjusted to provide adequate protection, the hydrogen coats the defects in the coating and polarizes in the negative direction (to a copper/copper sulfate reference electrode) over time the current and potentials remain relatively stable; changes in currents or potentials indicate a problem. An error-free measurement of negative 850 millivolts DC or more negative to the copper/copper-sulfate reference electrode proves the structure is a cathode and corrosion has been mitigated.

1.2.2 Corrosion

It is convenient to classify corrosion by the forms in which it manifests itself, the basis for this classification being the appearance of the corroded metal. Each form can be identified by visual observation, although, in some cases, magnification is required. Valuable information for the solution of a corrosion problem can often be obtained through careful observation of the corroded test specimens or failed equipment. Examination before cleaning is particularly desirable. Some of the eight forms of corrosion are unique, but all of them are more or less interrelated.

The eight forms of corrosion are: (1) Uniform Attack, (2) Galvanic or Two-Metal Corrosion, (3) Crevice Corrosion, (4) Pitting Corrosion, (5) Intergranular Corrosion, (6) Selective Leaching, (7) Erosion Corrosion, and (8) Stress Corrosion Cracking. This listing is arbitrary but covers practically all corrosion failures and problems. The forms are not listed in any particular order of importance. Below, the eight forms of corrosion are discussed in terms of their characteristics, mechanisms, and preventive measures. Hydrogen damage, although not a form of corrosion, often occurs indirectly as a result of corrosive attack and is, therefore, included in this discussion.

1.2.3 Alternating Current (AC) Corrosion

AC corrosion occurs when there is a source of AC current, typically from a high voltage overhead AC (OHAC) power-line, when there is a low soil resistivity - typically less than 5,000 ohm-cm and there is very small coating holidays. The AC corrosion pits typically have a tubercle of corrosion product at the pit. AC interference study modeling software can determine the mitigation solution to solve this problem. Typically, AC Corrosion mitigation is done in conjunction with high AC potentials and fault current mitigation.

1.2.4 AC Interference

AC interference occurs when a pipeline parallels a high-voltage overhead AC (OHAC) power-line. An interference study is required when this situation occurs as AC interference can cause high AC potentials along the pipeline (safety), can cause a fault condition between the pipeline and power-line and could cause AC corrosion to occur. The pipeline coating when exposed can have blisters/bubbles caused by the excessive AC. The interference study will use modeling software to determine what combination of interference may be occurring (if any) and provide the mitigation solution to solve the problem.

1.2.5 Uniform Attack

Uniform attack is the most common form of corrosion. It is normally characterized by a chemical or electrochemical reaction that proceeds uniformly over the entire exposed surface or over a large area. The metal becomes thinner and eventually fails. For example, a piece of steel or zinc immersed in dilute sulfuric acid normally dissolves at a uniform rate over its entire surface. A sheet iron roof shows essentially the same degree of rusting over its entire outside surface.

Uniform attack, or general overall corrosion, represents the greatest destruction of metal on a tonnage basis. This form of corrosion, however, is not of great concern from a technical standpoint, because the life of equipment can be accurately estimated on the basis of comparatively simple tests. Merely immersing specimens in the fluid involved is often sufficient. Uniform attack can be prevented or reduced by (1) materials, such as coatings, that reduce contact between metal and electrolytes, (2) inhibitors, or (3) cathodic protection.

1.2.6 Galvanic or Two-Metal Corrosion

A potential difference usually exists between two dissimilar-metals when they are immersed in a corrosive or conductive solution. If these metals are placed in contact (or otherwise electrically connected), this potential difference produces electron flow between them. Corrosion of the less corrosion-resistant metal is usually increased, and attack of the more resistant material is decreased, compared to the behavior of these metals when they are not in contact. The less resistant metal becomes anodic and the more resistant metal becomes cathodic. Usually the cathode or cathodic metal corrodes very little or not at all in this type of couple. Because of the electric currents and dissimilar-metals involved, this form of corrosion is called galvanic, bi-metallic or two-metal, corrosion. Galvanic corrosion is restricted to electrochemical corrosion caused by dissimilar-metal effects. It is electrochemical corrosion, but this document must restrict the term galvanic to dissimilar-metal effects for purposes of clarity.

1.2.7 Crevice Corrosion

Intense localized corrosion frequently occurs within crevices and other shielded areas on metal surfaces exposed to corrosives. This type of attack is usually associated with small volumes of stagnant solution caused by holes, gasket surfaces, lap joints, surface deposits, and crevices under bolt and rivet heads. As a result, this form of corrosion is called crevice corrosion or, sometimes, deposit or gasket corrosion.

1.2.8 Pitting Corrosion

Pitting is a form of extremely localized attack that results in holes in the metal. These holes may be small or large in diameter, but in most cases they are relatively small. Pits are sometimes isolated or so close together that they look like a rough surface. Generally a pit may be described as a cavity or hole with the surface diameter about the same as or less than the depth. Pitting is one of the most destructive and insidious forms of corrosion. It causes equipment to fail because of perforation with only a small percent weight loss of the entire structure. It is often difficult to detect pits because of their small size and because the pits are often covered with corrosion products. In addition, it is difficult to measure quantitatively and compare the extent of pitting because of the varying depths and numbers of pits that may occur under identical conditions. Pitting is also difficult to predict by laboratory tests. Sometimes the pits require a long time (several months or a year) to show up in actual service. Pitting is particularly vicious because it is a localized and intense form of corrosion, and failures often occur with extreme suddenness.

1.2.9 Intergranular Corrosion

Grain boundary effects are of little or no consequence in most applications or uses of metals. If a metal corrodes, uniform attack results since grain boundaries are usually only slightly more reactive than the matrix. However, under certain conditions, grain interfaces are very reactive and intergranular corrosion results. Localized attack at and adjacent to grain boundaries, with relatively little corrosion of the grains, is intergranular corrosion. The alloy disintegrates (grains fall out) or loses its strength. Intergranular corrosion can be caused by impurities at the grain boundaries, enrichment of one of the alloying elements, or depletion of one of these elements in the grain-boundary areas. Small amounts of iron in aluminum, wherein the solubility of iron is low, have been shown to segregate in the grain boundaries and cause intergranular corrosion. It has been shown that, based on surface tension considerations, the zinc content of a brass is higher at the grain boundaries. Depletion of chromium in the grain-boundary regions results in intergranular corrosion of stainless steels.

1.2.10 Selective Leaching

Selective leaching is the removal of one element from a solid alloy by corrosion processes. The most common example is the selective removal of zinc in brass alloys (dezincification). Similar processes occur in other alloy systems in which aluminum, iron, cobalt, chromium, and other elements are removed. Selective leaching is the general term to describe these processes, and its use precludes the creation of terms such as de-aluminumification, de-cobaltification. Parting is a metallurgical term that is sometimes applied, but selective leaching is preferred.

1.2.11 Erosion Corrosion

Erosion corrosion is the acceleration or increase in rate of deterioration or attack on a metal because of relative movement between a corrosive fluid and the metal surface. Generally, this movement is quite rapid, and mechanical wear effects or abrasion are involved. Metal is removed from the surface as dissolved ions, or it forms solid corrosion products, which are mechanically swept from the metal surface. Sometimes, movement of the environment decreases corrosion, particularly when localized attack occurs under stagnant conditions; this is not erosion corrosion because deterioration is not increased. Erosion corrosion is characterized in appearance by grooves, gullies, waves, rounded holes, and valleys and usually exhibits a directional pattern. In many cases, failures because of erosion corrosion occur in a relatively short time, and they are unexpected largely because evaluation corrosion tests were run under static conditions or because the erosion effects were not considered.

1.2.12 Stress-Corrosion Cracking

Stress-corrosion cracking refers to cracking caused by the simultaneous presence of tensile stress and a specific corrosive medium. Many investigators have classified all cracking failures occurring in corrosive media as stress-corrosion cracking, including failures due to hydrogen embrittlement. However, these two types of cracking failures respond differently to environmental variables. To illustrate, CP is an effective method for preventing stress-corrosion cracking; however, hydrogen-embrittlement may be caused when excessive current is applied, especially on stainless steel. Hence, the importance of considering stress-corrosion cracking and hydrogen embrittlement as separate phenomena is obvious. During stress-corrosion cracking, the metal or alloy is virtually unattacked over most of its surface, while fine cracks progress through it. This cracking phenomenon has serious consequences, since it can occur at stresses within the range of typical design stress.

1.2.13 Exothermic Welding

Exothermic welding is used in CP to connect a copper wire to a metallic structure, usually steel or cast-iron. It is a pyrotechnic composition of copper oxide, aluminum powder and magnesium powder. The magnesium powder is ignited with a spark gun or electronic ignition equipment. The aluminum powder serves as fuel, and melts the copper oxide, which bonds the wire to the structure. Although not explosive, it can create brief bursts of heat and high temperature in a small area.

1.2.14 Error-Free

Potential measurement error due to a voltage drop caused by current flowing through a resistor (the electolyte) between the reference electrode and the protected structure.

1.3 ADMINISTRATIVE REQUIREMENTS

After award of the contract, but prior to commencement of any work at the site, meet with the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Develop a mutual understanding relative to the administration of the value engineering, the safety program, preparation of the schedule of prices or the earned value report. Review shop drawings, other submittals, scheduling programming, execution of the work, and clear expectations of the "Interim Department of Defense (DD) Form 1354" submittal. Major subcontractors who will engage in the work must also attend.

1.4 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.

Submit all detail drawings at one time, as a single submittal, to demonstrate that the items have been properly coordinated and will function properly as a unit. Make a notation on each shop drawing submitted as to the item's specific use, either by a particular number referenced on the drawings or in the specifications, or by a description of its specific location.
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Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Preconstruction Survey

SD-02 Shop Drawings

Drawings; G[, [_____]]

Wiring and Schematic Diagram

Anode junction boxes

Contractor's Modifications; G[, [_____]]

SD-03 Product Data

Qualifications

Equipment; G[, [_____]]

Components; G[, [_____]]

Rectifiers; G[, [_____]]

Remote Monitoring Equipment; G[, [_____]]

Anodes; G[, [_____]]

Permanent reference electrodes; G[, [_____]]

Anode junction boxes

Cable and wire

Shunts

Extra Materials; G[, [_____]]

Spare Parts

SD-05 Design Data

Contractor's Modifications; G[, [_____]]

SD-06 Test Reports

Anode Connecting Cables

Rectifier Testing

SD-10 Operation and Maintenance Data

Cathodic Protection System; G[, [_____]]

Training Course;; G[, [_____]]

Contractor's Modifications; G[, [_____]]

SD-11, Closeout Submittals

Initial Cathodic Protection System Testing; G[, [_____]]

One Year Warranty Period Cathodic Protection System Field Test Report; G[, [_____]]

Final Acceptance Field Testing; G[, [_____]]

1.4.1 Material and Equipment Manufacturer Data

DATE	ISSUE NO.	REQUEST DATE	REQUESTED BY	REQUEST REF. NO.
MANUFACTURER NAME				
DESCRIPTION OF EQUIPMENT				

1.5 MAINTENANCE MATERIAL SUBMITTALS

1.5.1 Spare Parts

After approval of shop drawings, furnish spare parts data for each different item of material and equipment specified. The data must include a complete list of parts, special tools, and supplies, with current unit prices and source of supply.

After approval of shop drawings, furnish revised spare parts for any changes made from original submittal. One spare anode of each type must be furnished. In addition, supply information for material and equipment replacement for all other components of the complete system, including anodes, cables, splice kits and connectors, corrosion test stations, and any other components not listed above. Furnish [one reference electrode on a hand reel with 120 meters 350 feet of conductor], [one digital voltmeter that can be used in the maintenance of this CP system]. Demonstrate use of furnished equipment in actual tests during the training course. Provide a description of equipment of the pipe-to-soil protected structure and foreign structures at electrical isolation between the utility supplier and the facility piping.

1.5.2 Extra Materials

Furnish [one submersible reference electrode on a reel with enough wire to reach the bottom of the tank, or the bottom of the riser as required] and [one high input impedance multimeter that can be used in the maintenance of this CP system]. Demonstrate equipment in actual tests during the training course. Include a description of the equipment and measurement of the tank-to-water potentials, anode voltage, anode current and water level.

1.6 QUALITY CONTROL

1.6.1 Regulatory Requirements

Obtain the services of a corrosion expert to supervise, inspect, and test the installation and performance of the CP system. The term "corrosion expert" refers to a person, who by thorough knowledge of the physical sciences and the principles of engineering and mathematics, acquired by professional education and related practical experience, is qualified to engage in the practice of corrosion control of buried or submerged metallic structures.

1.6.2 Qualifications

The corrosion expert must be accredited or certified by NACE International, as a CP-4 CP Specialist or be a NACE International certified Corrosion Specialist or a registered professional engineer who has certification or licensing that includes education and experience in CP of the type of CP system being installed. The corrosion expert must have not less than [three] [five] [_____] years of experience in the type of CP for buried or submerged metallic structures under this contract. Submit evidence of qualifications of the corrosion expert including their name and qualifications certified in writing to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager prior to the start of construction. Certification must be submitted giving the name of the firm, the number of years of experience, and a list of not less than five of the firm's installations, three or more years old, that have been tested and found satisfactory.

1.6.3 Services of Corrosion Expert

The corrosion expert must make a minimum of three visits to the project site. The first of these visits will include obtaining water/electrolyte resistivity data, acknowledging the type of tank coatings to be used and reporting to the contractor the type of CP required (GACP or ICCP). Once the submittals are approved and the materials delivered, the corrosion expert will revisit the site to verify the materials meet submittal requirements, ensure the contractor understands installation practices and that the contractor is capable and qualified to complete the installation.

The "corrosion expert" will be available (but not necessarily be onsite the entire time) during the installation of the CP system to answer questions, approve any changes or additions required during construction, or to provide recommendations as required. The third visit is to complete the training and demonstrations to applicable personnel on proper testing and maintenance techniques and to complete testing the installed CP systems to ensure it has been installed properly and meets adequate CP criteria. An additional visit is required if the One-Year-Warranty-Period-Testing is required.

1.7 DELIVERY, STORAGE AND HANDLING

Storage area for corrosion material will be designated by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. If materials are not stored in a building, tarps or similar protection must be used to protect materials from inclement weather.

1.8 PROJECT/SITE CONDITIONS

1.8.1 Environmental Requirements

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NOTE: The environmental requirements with which the contractor must comply must be developed during the design process, included in the bidding documents, and made a part of the contract.

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1.8.2 Existing Conditions

Prior to start of any onsite construction activities, perform a Preconstruction Survey of the project site with the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager, and take photographs showing existing environmental conditions in and adjacent to the site. Submit a report for the record. Include in the report a plan describing the features requiring protection under the provisions of the Contract Clauses, which are not specifically identified on the drawings as environmental features requiring protection along with the condition of trees, shrubs and grassed areas immediately adjacent to the site of work and adjacent to the contractor's assigned storage area and access route(s), as applicable. The Contractor and the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager will sign this survey report upon mutual agreement regarding its accuracy and completeness. Protect those environmental features included in the survey report and any indicated on the drawings, regardless of interference that their preservation may cause to the work under the Contract.

1.9 WARRANTY

Provide equipment items that are supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

2.1.1 Corrosion Control System Description

Coating Systems (CS) are a critical factor in performance of all CP systems. All coatings, including coatings in structure guide specifications and Green Seal (GS) coatings, must be compatible with the structure and the CP system, and have high disbondment capabilities. A high resistance to cathodic disbondment is critical for long term service life of coatings on buried or submerged metallic structures under CP. Due to the limited voltage and current of galvanic anodes, a highly dielectric bonded coating is required to attain adequate using galvanic CP systems. For paints and coatings refer to Section 09 90 00 PAINTS AND COATINGS, steel coatings Section 09 97 13.00 40 STEEL COATINGS, interior coating of welded steel water tanks Section 09 97 13.16 INTERIOR COATING OF WELDED STEEL WATER TANKS. For discontinuity (Holiday) testing of new protective coatings on conductive substrates refer to NACE SP0188. Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates.

a. Construction Design Requirements (CDR) for the interior of steel water tanks are found in the UFGS. Section 33 16 15 WATER STORAGE STEEL TANKS NACE SP0196 and NACE SP0388, External CP of On-Grade Carbon Steel Tank Bottoms NACE SP0193.

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NOTE: Some state and local health agencies have listings of acceptable paint materials to be used for the interior of potable water tanks and to be used on the exterior of structures. As an example, the State of California will not allow vinyl paints to be applied due to air emission restrictions. The designer must contact the appropriate state and local authorities to determine if the paint systems are acceptable. If these systems are not acceptable, the designer must determine the best acceptable system and revise this specification accordingly. However, any deviation from this specification and American Water Works Association (AWWA} Standards must be submitted with justification to Civil Emergency Management Program (CEMP-ET) for approval.

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NOTE: Any AC test voltage over 15 VAC must be mitigated.

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NOTE: This specification covers a CP system for metal surfaces against corrosion by producing a continuous flow of direct current from impressed current or galvanic anodes to the metal to be protected. The anodes should be of sufficient size and quantity to protect the submerged metal items for a specified number of years before replacement.

****

****

NOTE: Provide impressed current CP and protective coatings for the interior submerged surfaces of potable water storage tanks, including bolted panel tanks in accordance with NSF/ANSI 61 and UFC 3-570-01. Galvanic Anodes are not allowed in potable water tanks, Reference: NSF/ANSI 61.

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****

NOTE: Construction Design Requirements (CDR) for the interior of steel water tanks are found in the

UFGS for water storage tanks Section 33 16 15 WATER STORAGE STEEL TANKS and NACE SP0388, Impressed Current CP of Internal submerged Surfaces of Steel Water Storage Tanks or NACE SP0196 Galvanic CP of Internal submerged Surfaces of Steel Water Storage Tanks.

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NOTE: This UFGS is for internal CP of Submersed Surfaces of Steel Water Storage Tanks. For the external CP of On-Grade Carbon Steel Tank Bottoms refer to UFGS for impressed current or galvanic CP for buried or submerged metallic structures and NACE SP0193.

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2.1.2 Design Requirements

****

NOTE: The following information must be shown on the drawings: Dimensions of tank, including riser (if tank is elevated), structural supports and overflow. Locations of all anodes, reference electrodes, junction boxes, test boxes, rectifiers, power connections, wire and conduit. Installation details for anodes and rectifiers. Electrical single-line diagrams, elevations, limiting dimensions, and equipment ratings which are not covered in the specification. Remote indicating or control requirements.

****

2.1.2.1 Drawings

Submit [six] [_____] copies of detail drawings consisting of a complete list of equipment and material including manufacturer's descriptive and technical literature, catalog cuts, contractor's modifications, results of system design calculations including water/electrolyte-resistivity, installation instructions and certified test data showing location of anodes and stating the maximum recommended anode current output density. Include in the detail drawings complete wiring and schematic diagrams, permanent reference electrodes and bonding and any other details required to demonstrate that the system has been coordinated and will function properly as a unit. Reference locations to two permanent facilities or mark points. Provide [one] [_____] electronic [digital] [PDF] [_____] copy and digital photos of the completed installation.

2.1.2.2 Summary of Services Required

Include the following scope of services:

a. CP Installation System requirements,

b. System testing,

c. Training,

d. Operating and maintenance manual,

e. Coating and holiday testing.

Take potential test measurements on all permanent reference electrodes, witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

Provide submittals identifying test locations on separate drawing, showing all metal to be protected and all CP equipment. Distinguish and identify test points equipment and protected metal.

2.1.3 Performance Requirements

The design must allow for synchronized interruption of all applied current.

2.1.3.1 Criteria of Cathodic Protection

The design must allow for synchronized interruption of all applied current. Criteria for adequate CP must be identified by the designer or the contractor's corrosion engineer and approved by the Government corrosion engineer. The method of voltage drop consideration must also be identified by the contractor's corrosion engineer and approved by the Government. Use of the 100 mV shift criteria is not applicable to bi-metallic structures.

****

NOTE: Refer to applicable current NACE International Standard Practice NACE SP0388 Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks or NACE International Standard Practice NACE SP0196 Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks to determine the appropriate criteria. Other criteria may not be applicable to this type of CP system(s) and structure being designed. The designer or the contractor's corrosion engineer may select the applicable criteria with approval of the Government.

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a. The measurements for the native potential measurement must be made before the CP system is energized. If CP has previously been applied, use the polarized potentials or the polarization decay potentials to determine if adequate CP has been achieved.

b. Determination of the on and polarized (instant off) potentials must be made with the protective current applied to the [structure] [tank] for a minimum of [2] [4] [7] [_____] [days].

c. The polarization decay (off) potentials must be made with the protective current off for a minimum of [24] [48] [_____] hours.

d. Polarized (instant off) potentials and polarization decay potentials must be made with the reference electrode at the same location.

e. The polarization decay will be the difference between the polarized potential and the polarization decay (off) potential made after the interruption of protective current.

2.1.3.1.1 Maximum Potential

The polarized potential between a copper/copper sulfate reference electrode and the tank [riser pipe] at any point must not be more negative than a negative 1.1 volts (with the protective current interrupted instantaneously or modulated). Do not use on potentials to determine maximum allowed potentials.

2.1.3.1.2 Tanks Subject to Icing Conditions

Suspend anodes in a manner similar to that in non-icing climates, except provisions must be made to prevent the anodes and suspending cables from being damaged by freezing or falling ice or by suspended floating flexible anode rings from the tank walls.

2.2 EQUIPMENT

2.2.1 Remote Monitoring

Remote monitoring equipment must be designed, manufactured and procured specifically for CP use and must be provided as per design and drawings to monitor [potential (requires permanent reference electrode)] [bond(s)] [interference bond] [test station(s) shunts] [_____] and must match or be compatible with previously installed remote monitoring equipment in use at the installation.

2.2.2 Corrosion Rate Monitoring

Corrosion probes must be designed, manufactured and procured specifically for the application and matched to the structure being protected. Manufacturer must match or be compatible with previously installed rate monitoring equipment in use at the installation.

2.2.3 Rectifiers

****

NOTE: Below about 500 volt-amperes of dc rating output, single phase selenium rectifiers cost less to acquire and operate than silicon rectifiers. Above 1000 volt-amperes silicon rectifiers are more economical for both single phase and three phase. Silicon rectifiers are more economical to repair.

****

2.2.3.1 Air Cooled Enclosure

NEMA ICS 6 Type [3] [3R] [3X] [4X] Air Cooled enclosure suitable for [wall] [post] [pad] mounting. Enclosures must be of 3.1 mm (11 gauge) steel or heavier. Enclosure must include front hinged door with [padlock hasp] [key lock, provide [three] [_____] keys.] [locks keyed alike.] [left side door] [right side door] fit with screened openings to provide for cooling by natural convection. Provide holes, conduit knockouts and threaded hubs of sufficient size and location. The cabinet and mounting support must be [painted][hot-dipped galvanized] [aluminum] [stainless] steel [according to the manufacturer's standards].

2.2.3.2 Oil Cooled Enclosure

NEMA ICS 6 Type 11-Oil Immersed Enclosure, suitable for pad mounting.

Enclosure must include top hinged door with [padlock hasp] [key lock, provide [three] [_____] keys.] [locks keyed alike.] Enclosures must be of 3.1 mm 11 gauge steel or heavier, with an accessible drain plug. The oil level must be clearly marked. The lid must be hinged and have quick release clamps to secure it in the closed position. A stop must limit the swing of the lid when opened. A compressible, oil resistant, positive sealing gasket must be provided. The gasket must return to its original shape upon release of lid pressure. The gasket attached to the tank or lid and joints must be free of gaps. Base mounting using 102 mm 4 inch high channels provided. Conduits entering the enclosure must be internally sealed and enter or exit above the oil fill line.

2.2.3.3 Explosion Proof Enclosure

NEMA ICS 6 Type 7 Explosion Proof Enclosure suitable for pad mounting. Enclosure must include top hinged lid with [padlock hasp] [key lock, provide [three] [_____] keys.] [locks keyed alike.] Enclosures must be of 3.1 mm 11 gauge steel or heavier, with an accessible drain plug. The oil level must be clearly marked. The lid must have quick release clamps to secure it in the closed position. A stop must limit the swing of the lid when opened. A compressible, oil resistant, positive sealing gasket must be provided. The gasket must return to its original shape upon release of lid pressure. The gasket attached to the tank or lid and joints must be free of gaps. Base mounting using 102 mm 4 inch high channels provided. Conduits entering the enclosure must be internally sealed and enter or exit above the oil fill line.

2.2.3.4 Cabinet Paint System

[The cabinet and mounting support must be [painted] [hot dipped galvanized] [aluminum] [stainless steel] with the manufacturer's standard painting system.] [The mounting support for the fiberglass cabinet must be [painted] [hot dipped galvanized] [aluminum] [stainless steel] with the manufacturer's standard painting system.]

****

NOTE: Below about 500 volt-amperes of dc rating output, single phase selenium rectifiers cost less to acquire and operate than silicon rectifiers. Above 1000 volt-amperes silicon rectifiers are more economical for both single phase and three phase. Silicon rectifiers are more economical to repair.

****

2.2.3.5 Transformers

UL 506 and NEMA ST 1, as applicable.

2.2.3.6 Electrical Ratings

Electrical ratings as follows: Input voltage at 60 Hz: [[115] [208] [230] volts single phase] [[208] [230] [460] volts three phase].

a. Output voltage, dc: [9] [12] [18] [24] [_____] volts [as indicated].

b. Output current, dc: [8] [16] [24] [32] [_____] amperes [as indicated].

The rectifier must be capable of supplying continuous full rated output at an ambient temperature of 44 degrees C 112 degrees F in full sunlight with expected life of 10 years minimum.

2.2.3.7 Rectifying Elements

Provide silicon diode rectifying elements, connected in such manner as to provide full-wave rectification. [Protect silicon diodes with selenium cells or varistors against overvoltage surges and by current limiting devices against overcurrent surges.]

2.2.3.8 Wiring and Schematic Diagram

Provide a complete wiring and schematic diagram of the power unit showing both the ac and the dc connections to anodes on the inside of the cabinet door. Show and label components.

2.2.3.9 Overload and Short Circuit Protection

Provide UL 489, single-pole, flush-mounted molded case circuit breaker, [magnetic] [thermal-magnetic] type, in the primary circuit of the rectifier supply transformer.

2.2.3.9.1 Circuit Breaker(s)

A [single] [double] [three]-pole, flush-mounted, fully magnetic, properly rated non-terminal type circuit breaker must be installed in the primary circuit of the rectifier supply transformer.

2.2.3.9.2 Fuses

Cartridge-type fuses conforming to NEMA FU 1. Provide suitable fuse holders in each leg of the D.C. circuit.

2.2.3.9.3 Surge Protection

Protect silicon diodes by use of AC and DC lightning arresters or metal oxide varistors against overvoltage surges and by current-limiting device against overcurrent surges.

2.2.3.10 DC Output Control

Provide adjustable DC output voltage by [transformer taps] [automatic controls].

2.2.3.10.1 Transformer Taps

****

NOTE: A minimum of five coarse and five fine taps is recommended to provide sufficient voltage adjustment. Variacs must not be used where subjected to corrosive or marine air atmospheres.

****

[Transformer taps, [5] [_____] coarse, [5] [_____] fine.] [Variac.] [_____].

2.2.3.10.2 Automatic Controls

Provide a control system capable of maintaining a preselected tank-to-water potential, within plus or minus 0.025 volt regardless of changes in water chemistry, temperature, or water level in the tank. [Provide separate dc output circuits, means of adjustment, reference electrodes, and metering for the tank bowl and riser pipe.] Make provisions for readily changing the range and limits of the operating potential. Refer to AWWA D104 Automatically Controlled Impressed-Current Cathodic Protection for the Interior Submerged Surfaces of Steel Water Storage Tanks.

2.2.3.11 Meters

Provide separate panel voltmeter and ammeter, not less than 63.5 mm 2 1/2 inch [round] [rectangular] 2 percent full scale accuracy at 30 degrees C 80 degrees F, temperature stability above and below 30 degrees C 80 degrees F of at least 1 percent per 5 degrees C 10 degrees F. Provide toggle switch for each meter.

2.2.3.12 Grounding Provisions

Grounding provisions must [be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.] [comply with NFPA 70 and UL 467 including a ground terminal in the cabinet.] The grounding conductor from the terminal to the earth grounding system must be solid or stranded copper not smaller than No. 6 AWG. Provide an earth grounding system consisting of one or more rods. Ground rods must be [copper-clad steel conforming to UL 467] [zinc-coated steel conforming to IEEE C135.30] [solid stainless steel] not less than [16] [19] mm [5/8] [3/4] inch in diameter by [2.4] [3.1] m [8] [10] feet in length. Drive rods full length into the earth. Sectional type rods may be used.

2.2.3.13 Resistance to Ground

****

NOTE: Remove this paragraph if not required in the project.

****

Measure the resistance to ground using the fall-of-potential method described in IEEE 81. The maximum resistance of driven ground must not exceed 25 ohms under normally dry conditions. If this resistance cannot be obtained with a single rod, [_____] additional rods not less than 1.8 m 6 feet on centers, or if sectional type rods are used, [_____] additional couple sections and drive with the first rod. In high-ground-resistance, use UL listed chemically charged ground rods. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, notify the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager immediately. Exothermically weld all connections below grade. Exothermically weld connections above grade or use UL 467 approved connectors.

****

NOTE: Exothermic welding is not recommended for splicing since it is a higher resistance splice that also degrades the conductivity of the conductors. The most recent mechanical or hydraulic-crimp splice results in no degradation of the conductivity of the conductors and is not dependent on the ambient conditions.

****

2.2.3.14 Efficiency

Overall efficiency of [65 percent] [90 percent] [_____] minimum when operated at full output.

2.2.3.15 Optional Rectifier Special Required Features

[1. An efficiency filter (choke) (may be required to improve the rectifiers efficiency). [capacitor] (A capacitor may also be required to be used in conjunction with the filter to further improve the efficiency and minimize noise.)

][2. Convenience Outlet mounted on Faceplate

][3. Safety shield panel covering Taps or all energized conductors on faceplate

][4. Stainless Steel Perforated screens on Air Cooled Rectifiers

][5. Heavy duty Draw-pull Stainless steel cabinet latch

][6. Separate Slide-out equipment racks for Transformer and Stack

][7. Additional [_____]coarse or [_____] fine voltage control link bar taps

][8. Quick-change, heavy-duty knobs for changing tap link bars Minimum 5/16" diameter

][9. Soldered tap changing studs 3/16" Grade XX

][10. Phenolic front panel

][11. Nickel Plated and double-nutted or soldered connections

][12. Terminal block for AC input wires

][13. Terminal block for Remote Monitoring Connections

][14. Primary tap change panel for dual input voltages (Single Phase models only)

]

2.2.3.16 Potable Water Storage Tanks

Provide CP and protective coatings for the interior submerged surfaces of potable water storage tanks, including bolted panel tanks in accordance with NSF/ANSI 61. Include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with an impressed current CP (ICCP) system, if specified, and NSF/ANSI 61. For bolted panel storage tanks, require the contractor to ensure all panels of a bolted panel storage tank are electrically continuous.

2.2.3.17 Fire Protection Water Storage Tanks

Fire protection water storage tanks are mission critical facilities and must be properly protected against corrosion. Provide an ICCP system for the interior submerged surfaces of all fire protection water storage tanks, including bolted panel tanks. When the backfill beneath an on-grade tank is corrosive, provide an ICCP system for the exterior bottom of the on-grade tank. Refer to UFGS Section 26 42 17 IMPRESSED CURRENT CATHODIC PROTECTION (ICCP) SYSTEM, NACE International SP0193 External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms. Include requirements in the contract specifying that the contractor is responsible for providing an interior coating system and ensuring that the coating system is compatible with the ICCP system. For bolted panel storage tanks, require the contractor to ensure all panels of a bolted panel storage tank are electrically continuous.

For Navy projects, allow ICCP or galvanic anode (GCP) systems for fire protection water storage tanks. See above references and UFGS Section 26 42 13 GALVANIC (SACRIFICIAL) ANODE CATHODIC PROTECTION (GACP) SYSTEM.

2.3 COMPONENTS

2.3.1 Junction Box Enclosures (Access and Physical Protection)

NEMA ICS 6, Type [3R] [4X] [_____] enclosure with [clamped cover] [Type [304] [316] stainless steel hinges and [clamped] [latched] cover] [and padlocked hasp]. Enclosure must be of [galvanized steel] [painted steel] [aluminum] [fiberglass] [non-metallic] construction with terminal board. Knockout for conduit must be the size and location as per design drawings.

2.3.2 Shunts for Junction Boxes

[MIL-I-1361.] [0.1] [0.01] [_____] ohm, [2] [8] ampere, accuracy plus or minus one percent, polycarbonate circuit board type, color coded for value recognition [red for 0.1 ohm shunt] [yellow for 0.01 ohm shunt] with Nickel plated brass posts and standard [64] 6.35 mm 0.25 inch holes on 2.54 cm 1 inch centers to fit test stations and terminal boards 0.01 ohm 6 ampere, accuracy plus or minus one percent, manganin (Trade Mark/alloy).

2.3.2.1 Nameplates

Provide nameplate in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM and ASTM D709. Provide laminated plastic nameplates for each enclosure as specified or as indicated on the drawings. Each nameplate inscription must identify the function. Nameplates will be melamine plastic, 3 mm 0.125 inch thick, white with [black] [_____] center core. Surface will be matte finish. Corners will be square. Accurately align lettering and engrave into the core. Minimum size of nameplates must be 635 mm 25 inch by 65 mm 2.5 inches. Lettering must be a minimum of 6.35 mm 0.25 inch high normal block style.

2.3.3 Terminal Boards

Provide terminal boards for anode junction boxes, bonding boxes, and test stations made of phenolic plastic [3] [6] [_____] mm [1/8] [1/4] [_____] inch thick with dimensions as indicated. Insulated terminal boards must have the required number of terminals (one terminal required for each conductor). Install solderless copper lugs and copper buss bars, shunts, and variable resistors on the terminal board as indicated. Test station terminal connections will be permanently tagged to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, reference electrodes and coupons).

2.4 MATERIALS

2.4.1 Anodes

****
NOTE: The actual compositions required must be determined to provide adequate and economical service. The anode material composition must be submitted for approval in accordance with "Submittals Procedures." Any deviation from chemical compositions listed must be approved by the government.
****

****
NOTE: Choose from anodes listed below. The chemical composition listed are examples only. The actual compositions required must be determined to provide adequate and economical service, and conform to the standards established by NACE.
****

2.4.1.1 Dimensions and Weights

****
NOTE: The following dimensions and weights of anodes are not all inclusive, additional sizes not included in the following tables may be available from various manufacturers.
****

Bare anode weight [4.1] [7.72] [9.7] [14.53] [_____] kg [9] [17] [20] [32] [_____] pounds not including core.

2.4.1.2 High-Silicon Chromium Bearing Cast Iron

****
NOTE: High-silicon cast iron anodes are rugged, long lasting, and commonly used in icing and non-icing climates. They are generally classified as relatively non-sacrificial having a consumption rate between 227 to 454 grams 0.5 to 1.0 pounds per ampere-year in most fresh waters.
****

ASTM A518/A518M. Provide cast iron anodes with the following characteristics:

a. Electrical resistivity: 72 micro-ohm-centimeter at minus 6.6 degrees C 20 degrees F (maximum).

b. Physical properties (nominal):

Tensile strength	103.4 MPa 15,000 psi
Compressive strength	689.4 MPa 100,000 psi

Brinell hardness	520
Density	7.0 grams per cubic centimeter
Melting point	1260 degrees C 2300 degrees F

c. Coefficient of expansion from zero to 100 degrees C 32 to 212 degrees F: 0.132 micrometers per degree C 0.733 micrometers per degree F.

2.4.1.2.1 Chemical Composition (Nominal)

Element	Percent by Weight Grade 2
Silicon	14.20-14.75
Manganese	1.50 Max.
Carbon	0.75-1.15
Chromium	3.25-5.00
Iron	Balance

2.4.1.2.2 Electrical Resistivity

Seventy-two microhm-centimeter at minus 7 degrees C 20 degrees F.

2.4.1.2.3 Physical Properties (Nominal)

Tensile strength	103.4 MPa 15,000 psi
Compressive strength	689.5 MPa 100,000 psi
Brinell hardness	520
Density	7.0 grams per cubic centimeter
Melting Point	1260 degrees C 2300 degrees F
Coefficient of expansion from 0 to 100 degrees C 32 to 212 degrees F	132 nanometer per degree C 0.733 micrometer per degree F

2.4.1.2.4 Anode Connecting Cables

Anodes must have connecting cables installed at the factory.

2.4.1.3 Aluminum Anodes

****

NOTE: Aluminum anodes are used in cases where annual or frequent replacement is required due to ice damage, and routine cleaning of the tank makes it possible to remove any expended or broken pieces

of anode stock from the tank before they accumulate. Also, see the technical note for "Precious Metal Anodes" regarding alternative anode systems for icing conditions. The designer must consider system maintainability impacts when selecting the anode system.

****

Provide aluminum anodes with composition and size conforming to NACE mandated requirements.

2.4.1.4 Precious Metal Anodes

****

NOTE: At installations where icing conditions exist and the scaling index of water is less than 20,000 (i.e., low hardness water), the designer must consider using precious metal anodes, such as platinized niobium, platinized titanium, or mixed metal oxide for CP systems. The consumption rate of precious metal anodes is less than that of other relatively non-sacrificial anodes. However, precious metal anodes are more vulnerable to damage and loss particularly during cleaning and reconditioning of the tank.

Selection of the configuration must be left to the designer of the system. Long, continuous wire from lengths of precious metal anodes may have an attenuating effect. This can be overcome by using an anode header cable connected to lengths of precious metal anodes at a common junction box. Such precious metal anode assemblies must be assembled with factory sealed and tested electrical connections to the anodes.

****

Provide [precious metal anodes] [_____], [solid] [composite] [wire] [rod] [expanded mesh] [ribbon] in form. Anode core must be [copper] [niobium] [titanium] with [platinum] [mixed metal oxide] [_____] coating with thickness of [_____] [millimeters] [mils].[Precious metal anode assemblies must have factory sealed and tested electrical connections to the anodes.] Size and length as indicated by engineering design drawings.

****

NOTE: mils is an abbreviated dimension in inches; millimeters is a metric dimension.

****

2.4.1.5 Mixed Metal Oxide (MMO) Anodes

Titanium Wire anodes with a mixed metal oxide crystalline electrically conductive coating with [1.5 mm 0.062 inches] [3.0 mm 0.118 inches] diameter.

Nominal Wire Size		Diameter Tolerance		Titanium		Active Surface Area		Weight	
mm	inches	mm	inches	Percent by Weight	Percent by Volume	m^2/m of Length	ft^2/ft of Length	g/m	lbs/ft
1.5	0.062	+0.062 -0.00	+0.007 -0.00	36.1	52.7	0.0051	0.017	13.7	0.009
3.0	0.118	+0.062 -0.00	+0.010 -0.00	17.1	29.0	0.010	0.033	0.042	0.042

Titanium Rod anodes with a mixed metal oxide crystalline electrically conductive coating with [3.175 mm 0.125 inches STD] [3.175 mm 0.125 inches XL] [6.35 mm 0.25 inches STD] [13.97 mm 0.55 inches] [19.05 mm 0.75 inches STD] diameter and [60.96 mm 24 inches XL] [121.92 mm 48 inches XL] length for use in [freshwater or brackish water] [seawater]. STD is standard MMO coating thickness, XL is extended life (greater MMO coating thickness). Titanium tubular anodes with a mixed metal oxide crystalline electrically conductive coating with [___] diameter, [___] length.

Anodes	Diameter		Length		Surface Area		Weight	
mm	cm	inches	cm	inches	m^2	ft^2	kg	lbs
1.6 x 100	1.6	0.063	100	39.4	0.050	0.78	0.21	0.47
2.5 x 50	2.5	1.00	50	19.7	0.039	0.42	0.18	0.40
2.5 x 100	2.5	1.00	100	39.4	0.079	0.84	0.35	0.77
3.1 x 76	3.1	1.22	76	30.0	0.076	0.82	0.32	0.70
3.1 x 122	3.1	1.22	122	48.0	0.121	1.30	0.50	1.10

****

NOTE: Wire, rod or tubular MMO anodes may be used underground with selected backfill, in deep anode beds, and are available in cannisters with selected backfill for use underground.

****

2.4.1.6 Platinized Niobium [Titanium] Anode

Standard platinized niobium anode must be [20 percent][40 percent] niobium by cross-sectional area with a copper core and [single][double] platinum thickness. The following table shows examples of platinized niobium anodes. Other platinized niobium anodes and platinized titanium may be specified.

20 Percent Niobium				
Diameter	**Niobium Thickness**	**Resistance**	**Platinum Thickness**	
inches	**inches**	**micro-ohm/ft**	**u-in.**	**u-in.**
0.75	0.038	22	300	600
0.5	0.025	50	200	400
0.375	0.019	89	150	300
0.25	0.013	201	100	200
0.188	0.009	356	75	150
0.125	0.006	806	50	100
40 Percent Niobium				
0.375	0.038	113	150	300
0.25	0.025	256	100	200
0.188	0.019	453	75	150
0.125	0.013	1025	50	100
0.093	0.01	1822	38	75
0.063	0.007	4102	25	50

2.4.1.7 Anode Life Test

The anode wire material must sustain current densities of 100 amperes per square meter 9.29 amperes per square feet in an oxygen-generating electrolyte for 20 years. The manufacturer must certify that a representative sample taken from the same lot used to construct the anode, has been tested and meets the following criteria. The test cell must sustain a current density of 10,000 amperes per square meter 9.29 amperes per square feet in a 15-weight percent sulfuric acid electrolyte at 66 degrees C 150 degrees F without an increase in anode to cathode potential of more than 1 volt. The cell containing the anode is to be powered with a constant current power supply for the 30-day test period. The representative sample must include a minimum of 125 mm 5 inch in length taken from the lot of wire that is to be used for the anode.

2.4.2 Galvanic Anodes

2.4.2.1 Magnesium

[ASTM B843] Chemical composition as mandated by NACE.

Bare anode weight: [7.71] [9.07] [14.51] [_____] kg [17] [20] [32] [_____] pounds [not including core].

2.4.2.2 Zinc

[ASTM B418, Type [I] [II].] [ASTM F1182.] [MIL-A-18001] Bare anode weight: [2.2] [2.27] [6.8] [13.61] [_____] kg [5] [15] [30] [_____] pounds [not including core].

Typical Zinc Bare Anode Sizes and Packaged Weight							
Bare Weight		Width		Height		Length	
kg	pounds	mm	inches	mm	inches	mm	inches
2.3	5	36	1.4	36	1.4	254	10
5.4	12	36	1.4	36	1.4	610	24
6.8	15	36	1.4	36	1.4	762	30
6.8	15	51	2.0	51	2.0	381	15
8.2	18	36	1.4	36	1.4	914	36
13.6	30	36	1.4	36	1.4	1524	60
13.6	30	51	2.0	51	2.0	762	30
20.4	45	51	2.0	51	2.0	1143	45
27.2	60	51	2.0	51	2.0	1524	60

2.4.3 Anode Wires and Cable

2.4.3.1 Anode Connecting Wire

****

NOTE: Any pinhole, cut, scratch or other damage to the anode cable exposing bare copper to the electrolyte will result in early failure of the CP system. For this reason, special, extra heavy insulation is used on anode cable. While it is often expedient to use the same type wire for the cathodic (negative) cable in order to avoid a mix-up in the field, the cathode cable is not subject to anodic failure and lesser insulation can be used.

****

Anode connecting wire must be No. [8] [_____] AWG stranded copper wire with type CP High Molecular Weight Polyethylene (HMWP) insulation, 2.8 mm 7/64 inch thick, 600 volt rating. Cable-to-anode contact resistance must be 0.003 ohms maximum.

2.4.3.2 Anode Header Cable

Cable for anode header and distribution must be No. [_____] AWG stranded copper wire with type [CP HMWP, 2.8 mm 7/64 inch thick insulation] [HMWPE protective jacketed cable with a fluoropolymer inner or primary insulation], 600-volt rating.

2.4.3.3 Polyethylene Insulation

Polyethylene insulation must comply with the requirements of ASTM D1248 and of the following types, classes, and grades:

2.4.3.3.1 HMWP

HMWP must be Type I, Class C, Grade E5.

2.4.3.3.2 High Density Polyethylene (HDPE)

HDPE must be Type III, Class C, Grade E3.

2.4.3.4 Attachment of Anode Lead Wire

Install anode lead wires at factory.

2.4.3.5 End-Connected Anode

[Drill] [Cast] a recess [150] [_____] mm [6] [_____] inches deep in one end of the anode. Attach the lead wire to the anode with an anchor device. Not more than 10 mm 1/2 inch of bare wire must protrude from the anchor device. Attachment must withstand a 1446 Newton 325 pound pull without loosening the wire or anchor device. Fill the recess with an epoxy sealing compound [, leaving sufficient space for a plug]. [Provide non-metallic plug flush with the anode end surface.] [Install a heat shrinkable anode cap over the attachment. Cap must extend not less than 65 mm 2 1/2 inches on the lead wire and 75 mm 3 inches on the anode.] Cable-to-anode contact resistance must not exceed 0.02 ohms.

2.4.3.6 Center-Connected Anode

Attach the lead wire to the center of the anode with an anchor device suitably fastened to the wire. Not more than 20 mm one inch of bare wire must protrude from the anchor device. Encapsulate [each side of] the connection point with [a minimum of 152 mm 6 inches [_____] of] high voltage insulating compound mastic and 102 mm 4 inches [_____] of epoxy resin. Attachment must withstand [4000] [6675] [_____] N [900] [1500] [_____] pounds pull without loosening the wire or anchor device. Provide a non-metallic [plug flush with the anode end] [end cap] to prevent chaffing of the anode lead wire. Cable-to-anode contact resistance must not exceed 0.02 ohms.

2.4.3.7 Mixed-Metal-Oxide-Anode Lead Wires

[[Solidly crimp] [and solder] the connection between the anode rod or ribbon and the lead wire. Seal the connection [with two layers of half lapped mastic tape covered with a heat shrinkable sleeve] [in cast epoxy].] [Tin and anneal the copper wire and hydraulically swage the tubular anode onto copper bushings in contact with the wire. Place a 28 mm 1 1/8 inch copper sleeve, inner diameter slightly larger than the tubular anode outer diameter, over the tube prior to swaging.] Cable to anode contact resistance must not exceed 0.02 ohms.

2.4.4 Permanent Reference Electrodes

Permanent reference electrodes must be [copper/copper-sulfate] [silver silver-chloride] [zinc] [Hydrocarbon-Proof Palladium (Pd/$PdCl_2$)] specifically manufactured for submersible use, [32] [_____] mm [1 1/4]

[_____] inch diameter, by [203] [255] [_____] mm [8] [10] [_____] inches long, [plastic] [_____] tube with a minimum surface sensing area of [_____] [_____] square centimeters[_____] square inches. Must never need recharging, maintenance, or recalibration. Must have impregnated membrane which keeps electrode electrolytes from drying out or getting the reference electrode electrolyte contaminated. Must have ion trap to prevent reference electrode damage from hydrogen sulfide or excess chloride ions. Provide electrodes with No. [10] [12] [_____] AWG, Rubber Heat (resistant) Wire (RHW) [RHW] Thermoplastic Heat and Water-resistant Nylon-coated (THHN) [THHN] [_____] cable of sufficient length to extend to the [rectifier] [junction box] without splicing. No splices are allowed below the high-water level. Reference electrodes will have a minimum 20-year life, stability of plus or minus 5 millivolts under 3 microamp load. The manufacturer must calibrate the PRC to 316 mV plus or minus 10mV referenced to a standard hydrogen electrode (SHE) and provide a calibration certificate detailing the results of the calibration. Procedures for evaluating the accuracy annually must be included in the Operation and Maintenance Manual.

****

NOTE: Refer to NACE TM0113-2013 Standard Test Method for Evaluating the Accuracy of Field-Grade Reference Electrodes and NACE TM0211-2011 Standard Test Method for Durability Test for Copper/Copper Sulfate Permanent Reference Electrodes for Direct Burial Applications for information for evaluating the accuracy or durability of the PRE.

2.5 ACCESSORIES

2.5.1 Shunt Resistors

[0.01] [_____] ohm, [6] [_____] amp, with an accuracy of plus or minus one percent. [Shunts must conform to MIL-I-1361 [rating as shown]].

2.5.2 Conduit

[UL 6, rigid galvanized steel.] [Outlet boxes: UL 514A and Fitting: UL 514B, threaded hubs.] [Metallic conduit and fittings to be polyvinyl-chloride coated in accordance with [NEMA RN 1, Type A40] [NEMA TC 2, Type EPC-40-PVC]]. Provide non-metallic conduit conforming to NEMA TC 2. Provide conduit support in accordance with NFPA 70.

2.5.3 Wires and Cables (other than Anodes)

****

NOTE: Refer to paragraph 2.4.3 Anode Wires and Cable for anode lead wires.

****

Provide copper wire conforming to ASTM B3 and ASTM B8. Wires terminating in a rectifier, junction box or test station must have a cable identification tag.

2.5.3.1 AC Power Supply Wiring

[UL 83, Type [THW] [THWN] [THHN]] [UL 44, Type RHW,] [UL 854, Type USE], stranded [solid] copper conductors, gauge (AWG) and color coded as indicated.

2.5.3.2 Reference Electrode Wire

[UL 83, Type [THW] [THWN] [THHN]] [UL 44, Type RHW,] stranded [solid] copper conductors, gauge (AWG) and color coded as indicated.

2.5.4 Wire Connectors

Safety Standard for Wire Connectors must conform to UL 486A-486B.

2.5.5 Splices

[Splices are not permitted in submerged sections of anode lead wire or anode header cable.] Provide splices with a compression connector on the conductor, and insulation and waterproofing using one of the following methods which are suitable for continuous submersion in water and comply with ANSI C119.1.

(1) Provide cast-type splice insulation by means of molded casting process employing a thermosetting epoxy-resin-insulating material applied by a gravity-poured method or pressure-injected method. Provide component materials of the resin insulation in a packaged form ready for convenient mixing without removing from the package.

(2) Gravity poured method must employ materials and equipment contained in and approved commercial splicing kit which includes a mold suitable for the cables to be spliced. When the mold is in place around the joined conductors, prepare the resin mix and pour into the mold.

(3) Provide [heavy wall] heat-shrinkable splice insulation by means of a thermoplastic adhesive sealant material which must be applied with a clean burning propane gas torch per manufacturer's instructions.

2.5.6 Insulating Tape

Safety Standard for Insulating Tape must conform to UL 510.

2.5.7 Bolting

ASTM A307, Grade B for bolts; ASTM A194/A194M, Grade 2 for nuts. Dimensions: ASME B18.2.1 for bolts, ASME B18.2.2 for nuts. Threads: ASME B1.1, Class 2A fit for bolts, Class 2B fit for nuts. Bolts must extend completely through the nuts and may have reduced shanks of a diameter not less than the diameter at the roof of threads.

2.5.8 Cable and Wire Identification Tags

[Laminated plastic material with black letters on a yellow background] [[Brass] [Stainless steel] material with stamped or engraved letters.] Print letters and numbers a minimum 5 mm 3/16 inch in size. Provide identifier legend [in accordance with the drawings] [_____].

2.5.9 Clevis Assemblies

Provide clevis assemblies, 6.35 mm 1/4 inch flat steel with a spool opening of 53.975 mm 2 1/8 inch, 114.3 mm 4 1/2 inch long to the centerline of the spindle. Provide porcelain spools, with an outside diameter of 57.15 mm 2 1/4 inch and an overall height of 53.975 mm 2 1/8 inch.

2.5.10 Pin Insulators

Provide pin insulator assemblies, 100 mm 4 inches long overall and 6.35 mm 1/4 inch diameter aluminum bolt 19 mm 3/4 inch long attached to the flat end with an aluminum nut and lock washer. Provide porcelain insulator of non-conducting material with hard glazed finish. Provide insulator with a hole through the bottom at least 13 mm 1/2 inch diameter.

2.5.11 Hand-hole Assemblies

Provide aluminum hand-hole covers, 175 mm 7 inches in diameter and 1.588 mm 1/16 inch thick and connected to insulating rubber gasket, 175 mm 7 inches in diameter and 3.175 mm 1/8 inch thick. Cut handholes 150 mm 6 inches in diameter. Provide hand-hole assemblies with 12.7 mm 1/2 inch bolts and 6.35 mm 1/4 inch plate clamping bars.

****

NOTE: The interiors and exteriors of bolted tanks are factory-coated. Electrical continuity must be verified and ensured across the bolted joints to ensure proper CP system operation.

****

2.5.12 Exothermic Weld Kits

Provide exothermic weld kits specifically designed by the manufacturer for welding the types of materials and shapes provided.

2.5.13 Manufacturer's Nameplate

Each item of equipment must have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.5.14 Field Fabricated Nameplates

****

NOTE: Use the following paragraph where nameplates are fabricated to identify specific equipment designated on the drawings.

****

ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device, as specified or as indicated on the drawings. Each nameplate inscription must identify the function and, when applicable, the position. Nameplates must be melamine plastic, 3 mm 0.125 inch thick, white with [black] [_____] center core. Surface must be matte finish. Corners must be square. Accurately align lettering and engrave into the core. Minimum size of nameplates must be 25 by 65 mm one by 2.5 inches. Lettering must be a minimum of 6.35 mm 0.25 inch high normal block style.

2.5.15 Cathodic Protection System Operation and Maintenance Manual

A Cathodic Protection System Operation and Maintenance Manual must outline the step-by-step procedures required for system startup, operation, adjustment of current flow, and shutdown. The manual must include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and their basic operating features. The manual must list routine maintenance procedures, recommendations for maintenance testing, possible breakdowns and repairs, and troubleshooting guides. The manual must include single line diagrams for the system as installed, instructions in making tank-to-reference electrode potential measurements and frequency of monitoring. The instructions must include precautions to ensure safe conditions during troubleshooting and repair of the CP system.

****
NOTE: Information must meet or exceed applicable sections in UFC 3-570-06, Operation and Maintenance: Cathodic Protection Systems. Applicable sections include Chapter 3.2.6 for water tank calibration for all tanks and chapter 3.2.1 for rectifier operational inspection for tanks with rectifiers.
****

PART 3 EXECUTION

3.1 SAFETY PRECAUTIONS AND HAZARDOUS LOCATIONS

Any operations that will generate heat, sparks, or flame include, but are not limited to, grinding, soldering, welding, cutting, brazing and exothermic welding. Ensure that hot work equipment is in good repair and used according to manufacturer's recommendations. A thorough safety inspection of the area must be conducted. Remove flammable gasses and liquids from the area. Combustibles in the work area must be moved or covered with fire-retardant blankets. One or more 20-pound ABC-type fire extinguisher(s) must be inspected before each planned use, and be readily available. A qualified fire watch must be present and remain 30 minutes after completion of the task(s). If work is being conducted in an area where explosive vapors could accumulate, adequate ventilation must be provided and air monitoring must be conducted.

3.2 INSTALLATION

3.2.1 Anode Installation

****
NOTE: Proprietary systems of anode installations are available for areas where icing is expected. For such areas, paragraph 3.2.1.1 "Icing Climate Requirements" should be included.
****

[IEEE C2] [NFPA 70].

3.2.1.1 Icing Climate Requirements

Suspend anodes in a manner similar to that in non-icing climates, except provisions must be made to prevent the anodes and suspending cables from being damaged by freezing or falling ice or by suspended floating flexible anode rings from the tank walls.

3.2.1.2 Anode Placement

Arrange anodes in the tank [and riser pipe] as shown in the drawings [so that protection can be provided to surfaces without exceeding potentials [in the vicinity of the anodes] that will be detrimental to coatings]. Suspend anodes from [roof] [wall] [plate] [structure] by means of factory-installed connecting wire designed to support the anodes in air [before submergence] without failure of the electrical wire insulation or the electrical conductors. Prevent contact between anode and tank surfaces such as man-access hatches, ladders, heater pipes, and stay rods.

3.2.1.3   Anode Hangers

Anode hangers must electrically insulate the anode suspending wire from the tank steel.

3.2.1.4   Handholes

Provide a handhole having a diameter of 150 mm 6 inches in the tank roof for each anode string to permit replacement or inspection of anodes.

3.2.2   Anode Connection

****

NOTE: A single split-bolt will work loose when wires it connects are moved. Minimum of two split bolts will prevent this from happening. In water tanks, split bolts are used (above water line only) because working space is limited and hydraulic or mechanical compression tools may be cumbersome and hazardous to use. At ground level or in trenches, compression tools can be used conveniently, and swedged sleeve connection produced by such tools is more reliable than split bolts.

****

3.2.2.1   Anode Lead Wires

Electrically connect anodes to the positive D.C. header cable with compression connectors or split bolts, or the header cable may terminate in a junction box for connection with all anode cables. Use a minimum of two split bolts for each connection if split bolts are used. Mark each of the wires terminating in the junction box.

3.2.2.2   Anode Header Cable

Provide header cable on the [underside of the roof] [wall] with electrically insulating hangers which enter the tank near the roof line from an externally mounted junction box. External wiring must be in conduit. Mark each of the wires terminating in the junction box.

3.2.2.3   Splices and Terminations

****

NOTE: Splices are not allowed below water level.

****

Locate under-roof electric wire splices above the high water line and seal water-tight using cast-type splice, gravity-poured method or heat shrinkable splice insulation as described in Section 2. Splices are not permitted in submerged sections of the anode lead wire or anode header cable.

3.2.3 Rectifiers

****
NOTE: For impressed current systems only.
****

3.2.3.1 Rectifier Installation

Location and mounting as indicated. Assemble and attach equipment enclosures to [wall] [post] [pad] in accordance with the manufacturer's instructions. Handle wires to prevent stretching or kinking the conductors or damaging the insulation. Use lubricants when pulling wires into conduits. Bond the equipment enclosures to a grounding electrode.

3.2.3.2 Rectifier Grounding

Locate ground rod(s) as indicated in drawings. Measure resistance to earth. If resistance to earth is more than 25 ohms, install additional ground rod(s) at a distance of 3.65 meters 12 feet or more and retest. Repeat if required. Low-resistance backfill, certified for use in grounding systems, may be required in exceptionally high soil resistivities using manufacturer's recommendations.

3.2.3.3 Wire-To-Tank Connections

Connect the structure wire to the tank [_____] [by use of an exothermic weld kit] [by brazing]. Clean the structure surface by scraping, filing, or wire brushing to produce a clean, bright surface. [Weld connections using the exothermic weld kits in accordance with the manufacturer's instructions. Test the integrity of the weld, prior to coating, by striking with a 908 gram 2 pound hammer.] [Cover connections and surrounding cleaned surface with an electrically insulating coating compatible with the existing coating.]

3.2.4 Permanent Reference Electrodes

3.2.4.1 Permanent Reference Electrode Verification

Verify permanent reference electrodes against a portable electrode in the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager before installation. Verify in a non-metallic container of water with the same composition as the tank to be protected. Permanent electrode must measure a reference potential agreeing with that measured by the portable electrode within plus or minus 0.010 volt when the sensing windows of the two electrodes being compared are not more than 2 mm 0.07 inch apart but not touching. Remove permanent reference electrodes not within this potential range from the construction site by the end of the day and replace at the contractor's expense. The testing provision applies to replacement permanent reference electrodes as well.

3.2.4.2 Installation

Provide permanent reference electrodes at points in the tank [and riser pipe] which monitor minimum and maximum [tank] [/riser]-to-water [potentials], regulate the automatic control system [_____], and maintain continuous immersion. Sensing windows of reference electrodes must be equidistant to and located within 25 mm one inch of the steel tank/riser pipe surface and be fixed in position, preventing contact with tank wall or appurtenances.

3.3 BOLTED AND RIVETED TANKS

Ensure electrical continuity of joining components.

3.4 GASEOUS EVOLUTION

Provide for possible evolution of gases from anode reaction and ventilation requirements.

3.5 FIELD QUALITY CONTROL

Field tests must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager or their designated representative. Advise the Contracting Officer or Contracting Officer's Representative [5] [_____] days prior to performing each field test. Quality control for the cathodic protection system must consist of the following:

a. Initial field testing by the contractor upon construction.

b. Government field testing after contractor has submitted initial field test report.

c. Warranty period field testing by the contractor.

d. Final field testing by the contractor after one year of service.

****

NOTE: Additional testing may be required based upon the specific project or design. All tests listed below may not be required. Designer must consider the project requirements for selection of test procedures. Specify 30-day notice for large systems to allow the Government corrosion engineer to be on-site during the initial and final field testing of the CP systems.

****

3.6 TESTS AND MEASUREMENTS

3.6.1 Native Potentials

Notify the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager a minimum of five (5) working days prior to each test. Base potential tests: At least [one week] [24 hours] [_____] after [installation of structure to be protected] [initial operation of structures containing fluids] and installation of the anodes, but before connection of anodes to the structure, measure base (native) structure-to-electrolyte potentials of the [structure]. Perform measurements at anode junction boxes, test stations and other locations suitable for test purposes. The locations of these measurements must be identical to the locations specified for potential measurements with anodes connected. Use the same measuring equipment that is specified for measuring protected potential measurements.

3.6.2 Protected Potentials

Systems must be tested and inspected by the contractor's corrosion engineer in the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager corrosion protection engineer or an approved representative. Notify the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager a minimum of five working days prior to each test. At least [one week] [24 hours] [_____] after native potential testing and connection of anodes to the structure, measure protected structure-to-electrolyte potentials. The locations of these measurements must be identical to the locations specified for native potential measurements. Use the same measuring equipment that is specified for measuring protected potential measurements. Record test data, including date, time, and locations of testing and submit report to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Contractor must correct and retest, at the contractors and Technical Experts expense, deficiencies in the materials and installation observed by these tests and inspections.

3.6.3 Reference Electrode Potential Measurements

Upon completion of the installation and with the entire CP system in operation, electrode potential measurements must be made using a copper/copper sulfate reference electrode and a potentiometer-voltmeter, or a direct-current voltmeter having an internal resistance (sensitivity) of not less than 10 megohms per volt and a full scale of 10 volts. The locations of these measurements must be identical to the locations used for baseline potentials. The values obtained and the date, time, and locations of measurements must be recorded. No less than eight (8) measurements will be made.

3.6.4 Holiday Test

Any damage to the protective coating during installation must be repaired before completion. After repair-coating has been applied, the entire structure, tank, wall or pipe must be inspected by an electric holiday detector with impressed current in accordance with NACE SP0188. The holiday detector will be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. Holidays in the protective coating must be repaired upon detection. Occasional checks of holiday detector potential will be made by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager to determine suitability of the detector. Labor, materials, and equipment necessary for conducting the inspection must be furnished by the contractor. The coating system must be inspected for holes, voids, cracks, and other damage during installation.

3.6.5 Rectifier Testing (impressed current systems only)

The purpose of the rectifier operational inspection is to determine the serviceability of all components required to impress current to the anodes of the impressed current system. The inspection must be thorough to ensure dependable current until the next inspection.

a. Before energizing the rectifier, visually check all rectifier components, shunt box components, safety switches, circuit breakers, and other system power components.

b. Tighten all accessible connections and check temperature of all the components.

c. Ensure all permanent reference electrode caps are removed and placed inside the rectifier cabinet for verification of removal and for use during tank cleaning.

****
NOTE: Do not increase the amount of current by requiring the S/E potential not to be more negative than -1150 mV with respect to a CSE of the tank. Excessive current may dis-bond the coating.
****

d. Startup testing of the rectifier must include voltage and current testing at all tap settings up to the level of protection or maximum of the rectifier rated current, whichever is the lowest. Do not apply excessive current to the tank. For automatic rectifiers, record each tap setting (if available) before switching to automatic potential control.

e. Using a dependable hand-held meter, measure the output voltage and current, and calibrate the rectifier meters, if present. For rectifiers with more than one circuit, measure the output voltage and current for each circuit using a dependable hand-held meter, and calibrate the rectifier meters, if present.

f. For systems with permanent reference electrodes, using a calibrated reference electrode, measure the potential difference to each installed permanent reference electrode by placing both electrodes together in the electrolyte with CP current off (may be tested before installation). If the difference is more than 10 mV, replace the permanent reference electrode. For rectifiers with potential voltmeters, using a dependable hand-held meter, measure the potentials for each voltmeter, and calibrate that rectifier meter.

g. Calculate the CP system circuit resistance of each circuit by dividing the rectifier DC voltage output of each circuit by the rectifier DC ampere output for that circuit.

h. Calculate the rectifier efficiency.

3.6.6 Initial Cathodic Protection System Testing

Initial field testing must be completed by the contractor upon completion of construction. Field testing must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager or their designated representative. Advise the Contracting Officer or Contracting Officer's Representative [5] [_____] days prior to performing each field test. Field testing must include native and protected potentials, anode current testing and permanent reference electrode testing.

****
NOTE: Additional testing may be required based upon the specific project or design.
****

The contractor must submit an initial field test report of the CP system.

Tank-to-electrolyte measurements, including initial potentials, protected potentials, anode outputs, rectifier and other required testing must be recorded on applicable forms. Identification of test locations, test station and anode test stations will coordinate with the as-built drawings and be provided on system drawings included in the report. The contractor must locate, correct, and report to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager any short circuits encountered during the checkout of the installed CP system.

3.6.7 Government Field Testing

****
NOTE: The requirements of paragraph entitled "Government Field Testing" are required for CP projects in either the Army, Navy, Air Force or Marines area. The designer must verify their applicability to projects outside the area with the appropriate Engineering Field Division (EFD) corrosion program manager.
****

The government corrosion [engineer] [program manager] must review the contractor's initial testing report. Approximately four weeks after receipt of the contractor's initial test report, the system will be tested and inspected in the contractor's presence by the government corrosion [engineer] [program manager]. The contractor must correct, at the contractor's expense, materials and installations observed by these tests and inspections to not be in conformance with the plans and specifications. The contractor will pay for all retesting done by the government engineer made necessary by the correction of deficiencies.
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****
NOTE: For CP projects in either the Army, Navy, Air Force or Marines area, select the appropriate options for paragraphs entitled "One Year Warranty Period Testing."
****

3.6.8 One-Year-Warranty-Period-Testing

The contractor must inspect, test, and adjust the CP system [quarterly] [semi-annually] [_____] for one year, [4] [2] [_____] interim inspections total, to ensure its continued conformance with the criteria outlined below. The performance period for these tests will commence upon the completion of all CP work, including changes required to correct deficiencies identified during initial testing, and preliminary acceptance of the CP system by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Copies of the One Year Warranty Period Cathodic Protection System Field Test Report, including field data, and certified by the contractor's corrosion engineer must be submitted to the Contracting Officer or Contracting Officer's Representative, the activity, and the geographic EFD corrosion [engineer] [program manager] [Contracting Officer] [Contracting Officer's Representative] [Technical Expert] [Project Manager].

3.6.9 Final Acceptance Field Testing

Conduct final acceptance field testing of the CP system utilizing the same procedures specified under the Initial Field Testing of the CP systems. The contractor will inspect, test, and adjust the CP system after one year of operation to ensure its continued conformance with the criteria outlined below. The performance period for these tests will commence upon preliminary acceptance for the CP system by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Copies of the Final Cathodic Protection System Test Report, certified by the contractor's corrosion engineer must be submitted to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager and the geographic EFD corrosion [engineer] [program manager] for approval, and as an attachment to the Operation and Maintenance Manual in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA. The government corrosion [engineer] [program manager] must review the contractor's final field testing report.

3.7 CLOSEOUT ACTIVITIES

3.7.1 Reconditioning of Surfaces

3.7.1.1 Concrete

Concrete must be 20 MPa 3000 psi minimum ultimate 28-day compressive strength with 25 mm one inch minimum aggregate conforming to [ASTM C94/C94M] [Section 03 30 00 CAST-IN-PLACE CONCRETE].

3.7.1.2 Restoration of Sod

Restore unpaved surfaces disturbed during the installation to their original elevation and condition. In areas where grass cover exists, it is possible that sod can be carefully removed, watered, and stored during construction operations, and replaced after the operations are completed. Where the surface is disturbed in a newly seeded area, re-seed the area with the same quality and formula of seed as that used in the original seeding. Seeding must be done as directed, in all unsurfaced locations where sod and topsoil could not be preserved and replaced. The use of sod in lieu of seeding will require approval by the Contracting Officer or the Contracting Officer’s Representative, Technical Expert and Project Manager.

3.7.1.3 Restoration of Pavement

Repair pavement, sidewalks, curbs, and gutters where existing surfaces are removed or disturbed for construction. Saw cut pavement edges. Graded aggregate base course must have a maximum aggregate size of 40 millimeters 1 1/2 inches. Prime base course with [liquid asphalt, ASTM D2028/D2028M, Grade RC-70] [_____] prior to paving. Match base course thickness to existing but must be atleast 150 millimeters 6 inches. Asphalt aggregate size must be 15 mm 1/2 inch [_____], asphalt cement must [conform to ASTM D3381/D3381M, Grade AR-2000] [_____]. Match asphalt concrete thickness to existing but must not be less than 50 millimeters 2 inches. Repair Portland cement concrete pavement, sidewalks, curbs, and gutters using 20.67 MPa 3,000 psi concrete conforming to [ASTM C94/C94M] [Section 03 30 00 CAST-IN-PLACE CONCRETE.] Match existing pavement, sidewalk, curb, and gutter thicknesses. Final surface must be the same level as the existing surface.

3.7.1.4 Cleanup

The contractor is responsible for cleanup of the construction site. All paper bags, wire clippings, must be disposed of as directed. Paper bags, wire clippings and other waste will not be put in bell holes or anodes excavation.

3.7.2 Training

3.7.2.1 Instruction to Government Personnel

During the warranty testing or at a time designated by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager, make available the services of a technician regularly employed or authorized by the manufacturer of the CP system for instructing Government personnel in the proper operation, maintenance, safety, and emergency procedures of the CP system. The period of instruction must be atleast [two] [four] [_____] hour[s] and at most [two] [_____] 8-hour working day[s]. Conduct the training at the jobsite or at another location mutually satisfactory to the government and the contractor. The field instructions will cover all of the items contained in the Operation and Maintenance Manual.

-- End of Section --