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USACE / NAVFAC / AFCEC **UFGS-26 42 17 (May 2021)**

Preparing Activity: USACE **Superseding**
UFGS-26 42 17.00 10 (November 2008)
UFGS-26 42 19.00 20 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated April 2024
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SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 42 17

IMPRESSED CURRENT CATHODIC PROTECTION (ICCP) SYSTEM

05/21

-- End of Section Table of Contents --

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SECTION 26 42 17

IMPRESSED CURRENT CATHODIC PROTECTION (ICCP) SYSTEM
05/21

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NOTE: This guide specification covers the requirements for a cathodic protection system using Impressed Current 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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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 applicable National Association of Corrosion Engineers (NACE) Standard for the type of structure being protected as listed in the references.

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NOTE: This specification covers a cathodic protection system for metal surfaces against corrosion by producing a continuous flow of direct

current from Impressed Current anodes to the metal to be protected. The anodes must be of sufficient size and quantity to protect the buried metal items for a specified number of years before replacement. The U.S. Department of Transportation has issued regulations requiring the application of cathodic protection to natural gas pipelines, liquid natural gas pipelines, petroleum pipelines, petroleum products pipelines, liquid petroleum gas pipelines, and petroleum storage facilities. Title 49 of the Code of Federal Regulations, Parts 191, 192, 193 and 195 must be consulted for applicable cathodic protection requirements for specific applications.
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NOTE: The following information must be on the drawings:

1. Locations of all underground pipes and structures.

2. Locations of all anode, anode wires, and structure wires.

3. Locations of all flanges and unions.

4. Locations of all equipment and components.

5. Installation details for structure connections, junction boxes, anodes and test stations.

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

7. Remote indicating or control requirements.
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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 B1.20.1	(2013; R 2018) Pipe Threads, General Purpose (Inch)
ASME B16.5	(2020) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.21	(2021) Nonmetallic Flat Gaskets for Pipe Flanges
ASME B16.39	(2020) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B18.2.1	(2012; Errata 2013) Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	(2022) Nuts for General Applications: Machine Screw Nuts, and Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2024) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A194/A194M	(2023) 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 2022) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
ASTM B3	(2013) Standard Specification for Soft or Annealed Copper Wire
ASTM B8	(2023) 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 C94/C94M	(2023) 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; R 2021) Cutback Asphalt (Rapid-Curing Type)
ASTM D3381/D3381M	(2018) Standard Specification for Viscosity-Graded Asphalt Binder for Use in Pavement Construction

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	(2023) National Electrical Safety Code
IEEE C135.30	(1988) Standard for Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 15589-2	(2012) Petroleum, Petrochemical and Natural Gas Industries - Cathodic Protection of Pipeline Transportation Systems - Part 2: Offshore Pipelines

NACE INTERNATIONAL (NACE)

NACE SP0106	(2018) Control of Internal Corrosion in Steel Pipelines and Piping Systems
NACE SP0176	(2007) Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production
NACE SP0177	(2019) Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems
NACE SP0186	(1986; R 2007) Application of Cathodic Protection for External Surfaces of Steel Well Casings
NACE SP0188	(2024) 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 SP0200	(2014) Standard Practice Steel-Cased Pipeline Practices
NACE SP0285	(2021) External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
NACE SP0286	(1997; R 2007) Standard Practice Electrical Isolation of Cathodically Protected Pipelines
NACE SP0388	(2018) Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks - Item No. 21040
NACE SP0607	(2007) Petroleum and Natural Gas Industries — Cathodic Protection of Pipeline Transportation Systems — Part 2: Offshore Pipelines
NACE SP21424	(2018) Alternating Current Corrosion on Cathodically Protected Pipelines: Risk Assessment, Mitigation and Monitoring
NACE TPC 11	(2008) A Guide to the Organization of Underground Corrosion-Control Coordinating Committees

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C119.1	(2023) Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600 Volts
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 TC 2	(2020) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023; ERTA 7 2023; TIA 23-15) National Electrical Code

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	(2022) 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	(2022) UL Standard for Safety Grounding and Bonding Equipment
UL 486A-486B	(2018; Reprint Jul 2023) 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; Reprint Jan 2022) UL Standard for Safety Specialty Transformers
UL 510	(2020; Dec 2022) UL Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013; Reprint Jun 2022) UL Standard for Safety Metallic Outlet Boxes
UL 514B	(2012; Reprint Mar 2024) UL Standard for Safety Conduit, Tubing and Cable Fittings
UL 854	(2020; Reprint Nov 2023) Standard for Service-Entrance Cables

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 a very small coating holiday. 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 electrolyte) 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 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

****

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 and Air Force projects.

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

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

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[, [_____]]

Anode junction boxes, bonding boxes, and test stations

Joint bonds

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

SD-03 Product Data

Qualifications

Equipment; G[, [_____]]

Anodes; G[, [_____]]

Anode junction boxes, bonding boxes, and test stations

Isolation flange kits

Dielectric unions

Wires

Cable and wire

Casings, isolation, and seals

Shunts

Permanent reference electrodes; G[, [_____]]

Spare Parts

SD-06 Test Reports

Tests and Measurements; G[, [_____]]

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

SD-10 Operation and Maintenance Data

Cathodic Protection System; G[, [_____]]

Training Course; G[, [_____]]

Cathodic Protection System, Data Package 5; G[, [_____]]

SD-11, Closeout Submittals

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

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

Final Cathodic Protection System Field Test Report; G[, [_____]]

1.4.1 Material and Equipment Manufacturer Data

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

DATE	ISSUE NO.	REQUEST DATE	REQUESTED BY	REQUEST REF. NO.

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 reference electrode on a hand reel with 120 meters 350 feet of conductor], [one high-input-impedance digital multimeter 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. Include a description of the equipment and measurement of the pipe-to-soil potentials, anode voltage, anode current and soil condition.

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 soil resistivity data, acknowledging the type of pipeline coatings to be used and reporting to the contractor if Impressed Current Cathodic Protection (ICCP) or Galvanic Anode Cathodic Protection (GACP) is required. 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 material are not stored in a building, tarps or similar protection must be used to protect material from inclement weather. Resack and add backfill to packaged anodes that are damaged as a result of improper handling or exposure to rain.

1.8 PROJECT/SITE CONDITIONS

1.8.1 Environmental Requirements

****

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.

****

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

A corrosion control system consists of several systems which work together to mitigate corrosion on buried or submerged metallic structures. Failure to comply with the requirements of any one of these systems may result in inadequate corrosion control and premature failure of the structure being protected. Each system's guide specifications must be included in the design and installation of a complete corrosion control system and must be adhered to in the design and execution of the corrosion control of a structure being protected. Determination of Need for CP must be made by government requirements and policy directives.

a. Construction Design Requirements (CDR) for protected structures are found in the UFGS for the structure being protected. For water storage tanks refer to Section 33 16 15 WATER STORAGE STEEL TANKS, NACE SP0388, and NACE SP0196, underground storage tanks NACE SP0285, aboveground storage NACE SP0193, fuel storage piping Section 33 52 40 FUEL SYSTEMS PIPING (NON-HYDRANT), aviation fuel piping Section 33 52 43.13 AVIATION FUEL PIPING, leak detection systems Section 33 01 50.31 LEAK DETECTION FOR FUELING SYSTEMS, offshore pipelines NACE SP0607 and ISO 15589-2, offshore structures and NACE SP0176, pipeline casings structures (railroad, highway and water crossing) NACE SP0200 and for well casings NACE SP0186.

b. Coating Systems (CS) are a critical factor in performance of an ICCP system. 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. For paints and coatings refer to Section 09 90 00 PAINTS AND COATINGS, and for discontinuity (Holiday) testing of new protective coatings on conductive substrates refer to NACE SP0188.

c. Mechanical Damage Systems (MDS) such as bedding and rock control barriers normally included in Structure GS may be required by design for some locations. Electrical Isolation is required for all galvanic anode CP systems. For an Electrical Isolation System (EIS) refer to NACE SP0286.

d. An Electrical Continuity System (ECS) of the protected structure is critical to the operation of the CP system. The types of joints such as bonding and couplings are normally included in Structure GS, this is particularly important to nonwelded pipelines to allow sufficient CP current to conduct to the entire structure.

e. Stray Current (Interference) Systems must be considered in design, monitored during construction, and interference testing must be completed during the final testing. Design must consider all other cathodic protection systems which may affect other systems or systems which may affect the project, including foreign systems. All foreign systems must be contacted for information and notification and any joint testing which may be required. Corrosion Coordinating Committees may exist. Reference NACE TPC 11.

f. Pipelines that parallel overhead high-voltage AC transmission power systems are subject to induced AC. Induced AC has several potential adverse impacts on the safety of personnel and pipeline integrity. Assuming that these conditions exist, there are several measures that can be taken to mitigate the induced AC present on a pipeline. These induced AC mitigation strategies are detailed in various international standards including NACE SP0177 and NACE SP21424.

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

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g. An Impressed Current CP Monitoring System is a solution for remote monitoring (and optionally controlling) different kinds of CP installations. Normally provides for measuring AC voltage input, DC voltage and current output. Optionally may be used to include potentials with permanent reference cells. Remote monitoring systems may be set to provide notifications of high and low alarms on any of the monitored inputs/outputs. Automated recording of all measurements may be scheduled and provide a historical database. Remote monitoring is widely used for underground pipelines used in oil and gas distribution systems, remote facilities such as missile launch facilities, for resistance bonds and remote test stations. These Monitoring Systems are detailed in various NACE international technical papers.

h. When a project is connecting to an existing infrastructure with CP the design must be compatible with the existing structure(s) CP system. Existing structures may have Impressed Current CP (ICCP) Anode Systems using Remote Anode Systems, Deep Anode Systems, Linear Anode Systems, or Distributed Anode Systems. Existing structures may also have Galvanic Cathodic Protection (GACP) Systems which may be distributed or remote. Existing structures might not have CP. They may use alternative methods of corrosion mitigation instead of CP such as Inhibitor System/Internal Corrosion Control. For control of internal corrosion in steel pipelines and piping systems refer to NACE SP0106. Due to the limited voltage and current of galvanic anodes the protected structure must be coated and isolated from other structures.

i. A highly dielectric bonded coating is required to attain adequate CP. Unbonded coatings block the protective current from the pipeline or structure and must not be used with CP. Failure to isolate other metallic structures will result in loss of protection. Isolation from other metallic structures must be maintained.

j. Continuity of the structure with low resistance is crucial to proper operation of a galvanic anode system. All joints must be continuous or be bonded to both sides of the joint.

k. A conductive electrolyte is required to allow current flow from the galvanic anodes. Use of galvanic anode systems are normally restricted to electrolytes with resistivities below 30,000 ohm-cm. Small well-coated structures such as coated valves, tees and elbows have very high resistance to earth in high resistance soils. Galvanic anodes in electrolytes over 30,000 ohms also have very high resistance to earth. High circuit resistance with the low voltage of galvanic anodes will not allow sufficient current to meet instant off or depolarization criteria. Additional anodes under these conditions will not noticeably increase the current applied to the structure. Reference SP0169 for criteria in high resistance electrolytes.

2.1.2 Design Requirements

2.1.2.1 Electrical Isolators

Isolators are required to isolate the [protected structure] [pipes] [_____] from any other structure. Provide isolators at all locations where the indicated [protected structure] [pipes] [_____] contact any other metallic structure. Provide locations and detailed drawings of required installations. Include any requirements for lightning protection, test stations, surge protection, or other requirements and include locations and details in design drawings.

2.1.2.2 Anode and Bond Wires

For each CP system, bond metallic components and structures that are not electrically continuous by installing bond wires between the various structures. Bonding of existing buried structures may also be required to preclude detrimental stray current effects and safety hazards. Return stray current to its source without damaging structures intercepting the stray current. Provide electrical isolation of underground facilities in accordance with acceptable industry practice. All tests must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

2.1.2.3 Surge Protection

Install approved zinc grounding cells or sealed weatherproof lightning and surge arrestor devices across isolation flanges or fittings installed in underground piping as indicated on the drawings. Provide gapless, self-healing, solid state type arrestor. Provide zinc anode composition conforming to ASTM B418, Type II. Provide number 4 AWG copper lead wires with High Molecular Weight Polyethylene (HMWPE) insulation. Zinc grounding cells prepackaged in backfill are acceptable; install as detailed on the drawings. Lightning arrestors or zinc grounding cells are not required for isolation flanges on metallic components used on non-metallic piping systems.

2.1.2.4 Non-metallic Pipe System

In the event pipe other than metallic pipe is approved and used in lieu of metallic pipe, protect all metallic components of this pipe system with CP. Submit detailed drawings of CP for each component to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager for approval within 45 days after date of receipt of notice to proceed, and before commencement of any work.

2.1.2.5 Coatings

Provide coatings for metallic components as required for metallic fittings. Complete and test protective coating on each metallic component (such as valves, hydrants and fittings). Provide coating as required for underground metallic pipe. Each test must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Select, apply, and inspect coatings as specified in these specifications. The use of non-metallic pipe does not change other requirements of the specifications. Submit any deviations due to the use of non-metallic pipe for approval.

2.1.2.6 Tracer Wire

When a non-metallic pipeline is used to extend or add to an existing metallic line, thermit-weld No. 8 AWG copper wire with Thermoplastic Heat and Water-resistant Nylon-coated (THHN) insulation to the existing metallic line and run the length of the new non-metallic line. Use this wire as a locator tracer wire and to maintain continuity to any future extensions of the pipeline.

2.1.2.7 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, results of system design calculations including soil-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, isolation fittings, test stations, 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.

2.1.2.8 Summary of Services Required

Include the following scope of services:

a. Close-interval potential surveys,

b. CP Installation System,

c. System testing,

d. Casing corrosion control,

e. Interference testing,

f. Training,

g. Operating and maintenance manual,

h. Isolation testing and bonding testing,

i. Coating and holiday testing.

2.1.2.9 Contractor's Modifications

The specified system is based on a complete system with [galvanic in GACP] [Impressed Current in ICCP] & [Galvanic or Impressed Current (as applicable) in SWT] anodes. The contractor may modify the CP system after review of the project, site verification, and analysis, if the proposed modifications include the anodes specified and will provide better overall system performance.

a. Submit [six] [_____] copies of detail drawings showing proposed changes in location, scope of performance indicating any variations from, additions to, or clarifications of contract drawings. Show proposed changes in anode arrangement, anode size and number, anode materials and layout details, conduit size, wire size, mounting details, wiring diagram, method for electrically-isolating the structure, and any other pertinent information for proper installation and performance of the system. Reference locations to two permanent facilities or mark points. 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. The modifications must be fully described and must be approved by the Contracting Officer. Provide [one] [_____] electronic [digital] [PDF] [_____] copy and digital photos of the completed installation.

b. The proposed system must achieve performance requirements found in section 2.1.3 Performance Requirements, meet the criteria of CP and be verified by testing requirements in section 3.6.1 Tests and Measurements.

2.1.2.10 Tests of Components

Perform a minimum of four tests at each metallic component in the piping system. Two measurements must be made directly over the anodes and the other two tests must be over the outer edge of the component, but at the farthest point from the anodes. Provide a field drawing showing the component, the structure, all components of the CP system and their relationship to each other. Also provide a narrative describing how the CP system will work and the testing at each component. Components requiring CP must include but not be limited to the following:

a. Pipes under the floor slab or foundations.

b. Post Indicator Valve (PIV).

c. Shutoff valves.

d. Metallic pipes extended from aboveground locations.

e. Connectors or change-of-direction devices.

f. Metallic pipe components or sections.

g. Backflow preventers.

h. Culverts.

i. Casings.

2.1.2.11 Electrical Potential Measurements

Make all potential tests at a minimum of 3 m 10 foot intervals witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Provide submittals identifying test locations on separate drawings, showing all metal to be protected and all CP equipment. Distinguish and identify test points equipment and protected metal.

2.1.2.12 Typical Metallic Components on Non-metallic Systems

2.1.2.12.1 Metallic Components

As a minimum, protect each metallic component with two galvanic anodes. This number of anodes is required to achieve minus 850 millivolts "instant off" potential on the metallic area and at the same time not provide overvoltage above 1200 millivolts "instant off." As a minimum, the galvanic anode unpackaged weight must be [4.1] [7.7] [_____] kg [9] [17] [_____] pounds. Locate the galvanic anodes on each side of the metallic component and route through a test station.

2.1.2.12.2 Fire Hydrants

Provide fire hydrant pipe components with a minimum of two anodes. These magnesium anodes must have an unpackaged weight of 7.7 kg 17 pounds.

2.1.2.12.3 Pipe Under Concrete Slab

Pipe under concrete slab must have a minimum of [2] [3] [_____] magnesium anodes. These magnesium anodes must have an unpackaged weight of [4.1] [7.7] [_____] kg [9] [17] [_____] pounds. Pipe under concrete slab must have [1] [2] [_____] permanent reference electrodes located under the slab. Locate one permanent reference electrode where the pipe enters the concrete slab. Route all conductors to a test station.

2.1.2.12.4 Valves

Protect each valve with [1] [2] [_____] magnesium anodes. The magnesium anode must have an unpackaged weight of [4.1] [7.7] [_____] kg [9] [17] [_____] pounds.

2.1.2.12.5 Metallic Pipe Component or Section

Protect each section of metallic pipe with [2] [3] [_____] magnesium anodes. The magnesium anodes must have an unpackaged weight of [4.1] [7.7] [_____] kg [9] [17] [_____] pounds.

2.1.2.12.6 Connectors or Change-of-Direction Devices

Protect each change-of-direction device with [2] [3] [_____] magnesium anodes. The magnesium anode must have an unpackaged weight of [4.1] [7.7] [_____] kg [9] [17] [_____] pounds.

2.1.2.13 Metallic Component Coating

Coatings for metallic components will be required for metallic fittings as indicated. These metallic fittings will include fire hydrants, tees, elbows, and valves. Coatings must be selected, applied, and inspected as specified in the coating specifications referenced and be compatible with the structure being protected. All coatings must be in accordance with all applicable Federal, State, and local regulations. Unbonded coatings must not be used with CP.

2.1.2.14 Location of Test Stations

Provide test stations of the type and location shown and [curb box] [post] [wall] mount. Provide buried isolation joints with test wire connections brought to a test station. Reference all test stations with GPS coordinates. Unless otherwise shown, locate other test stations as follows:

a. At 300 m 1,000-foot intervals or less.

b. Where the pipe or conduit crosses any other metal pipe.

c. At both ends of casings under roadways and railways.

d. Where both sides of an isolation joint are not accessible above ground for testing purposes.

2.1.2.15 Electrical Isolation of Structures

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NOTE: The CP system will fail unless full consideration is given to specifications for electrically isolating pipe joints, electrically conductive pipe joints, and casing cradles and seals. Mechanical and electrical specifications must reference paragraphs "Electrically Isolating Pipe Joints" and "Electrically Conductive Couplings."

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As a minimum, provide isolating flanges or unions at the following locations:

a. Connection of new metallic piping or components to existing piping.

b. Pressure piping under floor slab to a building.

Provide isolation at metallic connection of all lines to existing system and where connecting to a building. Additionally, provide isolation between [water] [_____] or [gas] [_____] [forced main] line; and foreign pipes that cross the new lines within 3.05 m 10 feet. Install isolation fittings, including isolating flanges and couplings, aboveground or in a concrete pit.

2.1.2.15.1 Gas Distribution Piping

Provide electrical isolation at each building riser pipe to the pressure regulator, at all points where a short to another structure or to a foreign structure may occur, and at other locations as indicated on the drawings.

2.1.2.15.2 Isolation Joint Testing

An isolator checker or insulation tester will be used for isolation or insulating joint (flange or dielectric) electrical testing.

2.1.2.15.3 Underground Structure Coating

This coating specification takes precedence over any other project specification and drawing notes, whether stated or implied, and also applies to the pipeline or tank supplier. Variance in coating quality is not allowed by the contractor or Base Construction Representative without the written consent of the designer. All underground metallic pipelines and tanks to be cathodically protected must have a high quality factory-applied coating. This includes all carbon steel, cast-iron and ductile-iron pipelines or vessels. Select, apply, and inspect coatings as specified. If non-metallic pipelines are installed, coat all metallic fittings on pipe sections in accordance with this specification section.

a. The nominal thickness of the metallic pipe joint or other component coating must be [0.2][0.4][0.6][1.0][1.5][_____] mm [8][16][24][40][60][_____] mils, plus or minus 5 percent.

b. Apply pipe and joint coating for factory applied or field repair material as recommended by the manufacturer. Coating must be one of the following:

    (1) Continuously extruded polyethylene and adhesive coating system.
    (2) Polyvinyl chloride pressure-sensitive adhesive tape.
    (3) High density polyethylene/bituminous rubber compound tape.
    (4) Butyl rubber tape.
    (5) Coal tar epoxy.

2.1.2.15.4 Field Joints

Coat all field joints with materials compatible with the pipeline coating compound. Apply the field joint coating material to an equal thickness as the pipeline coating. Do not use unbonded coatings for these buried metallic components. This includes the elimination of all unbonded polymer wraps or tubes. Once the pipeline or vessel is set in the trench, conduct an inspection of the coating. This inspection must include electrical holiday detection. Repair any damaged areas of the coating. The Contracting Officer or the Contracting Officer's Representative, Technical Expert or Project Manager must be asked to witness inspection of the coating and testing using a holiday detector.

2.1.2.15.5 Inspection of Pipe Coatings

Any damage to the protective coating during transit and handling must be repaired before installation. After field coating has been applied, inspect the entire pipe using an electric holiday detector in accordance with NACE SP0188 using a full-ring, spring-type coil electrode. The holiday detector must be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. Upon detection, immediately repair all holidays in the protective coating. Occasional checks of holiday detector, operation will be made by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager to determine suitability of the detector. Provide all labor, materials, and equipment necessary for conducting the inspection.

2.1.2.15.6 Protective Coating for Aboveground Piping System

Provide finish painting conforming to the applicable paragraph of Section 09 90 00 PAINTS AND COATINGS and as follows:

2.1.2.15.7 Ferrous Surfaces

Touch-up shop-primed surfaces with ferrous metal primer. Solvent-clean surfaces that have not been shop-primed. Surfaces that contain loose rust, loose mil scale, and other foreign substances must be mechanically-cleaned by power wire-brushing and primed with ferrous metal primer. Finish primed surface with two coats of exterior oil paint and vinyl paint.

2.1.3 Performance Requirements

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

2.1.3.1 Criteria of Cathodic Protection

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. The 100 mV shift criteria are not applicable to bi-metallic structures.

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NOTE: Refer to applicable current NACE International Standard Practice NACE SP0169, NACE 0186, NACE 0193, NACE SP0285, NACE 0388 and NACE 0607 or other applicable NACE Standards for the type of metal and the type of metallic structure being protected to determine the appropriate criteria. Not all criteria may be applicable to the type of CP system(s) and structure being designed, and the designer or the contractor's corrosion engineer may select the applicable criteria with approval of the government. If no other criteria are applicable to the structure, use SP0169 Section 6, Criteria.

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a. Determination of the on and polarized (instant off) potentials must be made with the protective current applied to the [structure] [tank] [pipeline] [coupon] for a minimum of [1] [2] [4] [_____] [days].

Polarized potentials may be determined using a coupon test station (Error-Free (IR Free) test station). Polarized potentials must be determined by interrupting all the current being applied to the structure or coupon.

b. The potential measurements for the native measurement and the polarized potential must be made with the reference electrode at the same exact location. The polarization decay measurements must also be made with the reference electrode at the same exact location as the polarization potential.

c. The polarization decay measurements will be the difference between the polarized potential and a voltage measurement made [24] [48] [_____] hours after the interruption of protective current.

2.1.3.1.1 Steel

A negative polarized potential of 0.85 volts (850 millivolts) or more negative. The voltage must not be more negative than a negative polarized potential of 1.200 volts (1200 millivolts).

2.1.3.1.2 Aluminum

Aluminum underground components must not be protected to a potential more negative than 1200 millivolts, measured between the underground component and a saturated copper/copper sulfate reference electrode contacting the earth, directly over the metallic component. Resistance, if required, must be inserted in the anode circuit within the test station to reduce the potential of the aluminum to a value which will not exceed a potential more negative than minus 1200 millivolts. Voltage shift criterion must be a minimum negative polarization shift of 100 millivolts measured between the metallic component and a saturated copper/copper sulfate reference electrode contacting the earth, directly over the metallic component. The polarization voltage shift must be determined as outlined for iron and steel.

2.1.3.1.3 Copper Piping

For copper piping, the following criteria must apply: A minimum of 100 millivolts of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. The polarization voltage shift must be determined as outlined for iron and steel.

2.2 EQUIPMENT

2.2.1 Remote Monitoring

Remote monitoring equipment must be designed, manufactured and procured specifically for CP use and should 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. Rectifier monitoring must include DC Current output(using rectifier shunt), DC Voltage Output,[AC voltage input][AC voltage input to stacks][_____]. Remote Monitoring must include ability to remotely control current interruption using a [solid state relay with surge suppressor][mercury switch] interrupting the [negative structure lead][AC Voltage to stacks] [AC Rectifier input]. [Software must be compatible with previously installed equipment and allow for group interruption.]

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

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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.

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Rectifier will be [Air Cooled][Oil Immersed][Explosion Proof].

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 Construction

Cabinets are constructed of [not lighter than 1.56 mm 16 gauge [steel] [hot dipped galvanized steel] [stainless steel] [aluminum]] [molded fiberglass reinforced polyester], and provided with a full door. The enclosure must have oil-resistant gasket. The door must be hinged and have a hasp that will permit the use of a padlock. The cabinet must be fitted with screened openings of the proper size to provide for adequate cooling. Holes, conduit knockouts, or threaded hubs of sufficient size and number conveniently located.

2.2.3.5   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.]

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NOTE: The enclosure must not be used in areas prone to flooding unless required for hazardous locations. Provisions must be made for flooding.
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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   Rectifier Stacks

Rectifying elements must be [silicon diodes] [selenium cells] connected to provide full-wave rectification. Silicon diodes must be protected by selenium surge cells or varistors against over-voltage surges, and by current-limiting devices against over-current surges.

2.2.3.8   Transformer

Transformer must conform to UL 506.

2.2.3.9   Circuit Breaker

A [single] [two] [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. Properly rated secondary magnetic circuit breaker between rectifier supply transformer and stacks, two on three phase rectifiers.

2.2.3.10 Fuses

Cartridge-type fuses with suitable fuse holders must be provided in each leg of the DC circuit. Properly rated secondary fuse between rectifier supply transformer and stacks, two on three phase rectifiers.

2.2.3.11 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.

2.2.3.12 Surge Protection

Install approved sealed weatherproof lightning arrestor devices for the AC input and the DC output. The arrestor must be gapless, self-healing, solid state type.

2.2.3.13 Wiring

Install wiring in accordance with NFPA 70 utilizing type [THHN] [THWN] [PVC] Thermoplastic Wire (TW) [TW] Rubber Heat (resistant) Wire (RHW) [RHW] [polyethylene] insulation. Fittings for conduit and cable work must conform to UL 514A. Outlets and conduit must be of the threaded hub type with gasketed covers. Conduit must be securely fastened at 2.4 m 8 foot intervals or less. Splices made in outlet fittings only. Conductors must be color coded for identification. Wiring for anode header and distribution must be No. [2] [_____] AWG stranded copper wire with type [HMWPE] [Dular/Halar] [Dual Extrusion HALAR/HMWPE] [Dual Extrusion Kynar (PVDF)] Direct Burial Cable insulation.

2.2.3.14 Shunt Resistors

MIL-I-1361. Shunt must be located on the rectifier front panel and clearly marked with current and voltage for verification of panel ammeter. Install shunts calibrated in millivolts per amp with amp capacity at or slightly under rectifier output in series in the anode or the structure circuit between the stacks and the rectifier output.

2.2.3.15 DC Output Control

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

2.2.3.16 Output Voltage and Current Metering

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.

2.2.3.17 Efficiency

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

2.2.3.18 Filter Chokes and Capacitors

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

2.2.3.19 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. The earth grounding system must consist of one or more ground rods. Ground rods must be of [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. Rods are driven full length into the earth. Sectional type rods may be used.

2.2.3.20 Resistance to Ground

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

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The resistance to ground must be measured using the fall-of-potential method described in IEEE 81. The maximum resistance of driven ground is not to 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 sections may be coupled and driven with the first rod. In high-ground-resistance, UL-listed chemically-charged ground rods may be used. 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. Connections below grade must be fusion welded. Connections above grade must be fusion welded or must use UL 467 approved connectors.

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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.

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2.2.3.21 Wiring Diagram

A complete wiring diagram of the power unit showing both the AC supply and the DC connections to anodes located on the inside of the cabinet door. All components must be visible and labeled.

2.2.3.22 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)

]

2.2.4 Polarization Cell Replacement (PCR) and (PCRH) for Hazardous Locations

PCRs and PCRHs must be designed, manufactured, and procured specifically for the application and must exceed the modeled AC steady-state current and fault conditions. For hazardous locations, the PCRH model must be used.

Characteristic	**PCR**	**PCRH**
AC steady-state current, rms	45A, 80A	45A
AC fault current, rms. at 0.5s	3.7 kA to 15 kA	3.7 kA to 15 kA
Lightning current, 8x20 micros, peak	100 kA	100 kA

Characteristic	PCR	PCRH
Hazardous location certification	Division 2, Zone 2	Division 1, Zone 1
Rain Proof, IP66	Yes	Yes
Submersible, IP68 or NEMA 6P	Optional	No

PCRs must be installed with a protective ground-based enclosure to secure the cable connections and prevent electrical hazards. The PCRH must be installed with an explosion-proof enclosure and must be [flange] [pole] [wall] mounted. Structure and Grounding conductors must be properly sized for the application.

AC Fault Current Rating	Minimum Wire Size (AWG)	Minimum Wire Size (Metric)
1.2 kA, 2kA, 3.7 kA	#6	$16mm^2$
5kA 9kA 10kA	#2	$35mm^2$
14kA 15kA	#2/0	$70mm^2$

2.2.5 Solid State Decoupler (SSD)

SSDs must be designed, manufactured, and procured specifically for the application and must exceed the modeled AC steady-state current and fault conditions. For hazardous locations, the PCRH model must be used. SSDs must be installed with a protective ground-based enclosure to secure the cable connections and prevent electrical hazards.

Characteristic	SSD
AC steady-state current, rms	45A
AC fault current, rms. at 0.5s	1.2 to 5 kA
Lightning current, 8x20micros, peak	75-100 kA
Hazardous location certification	Division 2, Zone 2

Characteristic	SSD
Rain Proof, IP66	Yes
Submersible, IP68 or NEMA 6P	Yes

2.3 COMPONENTS

2.3.1 Test Stations

2.3.1.1 Flush Mounted

NEMA ICS 6. Metallic or non-metallic with terminal board, [5] [8] [_____] terminal posts [and lockable lid]. A non-metallic enclosure must be molded of glass filled polycarbonate and urethane coated or Acrylonitrile Butadiene Styrene (ABS) plastic [and mounted on a 500 mm 18 inch length of PVC conduit]. The unit must be of standard design, manufactured for use as a CP test station, complete with cover, terminal board, shunts, and brass or Type [304] [316] stainless steel hardware. The terminal board must be removable for easy access to wires. [Provide traffic valve box capable of withstanding [H-20] [_____] traffic loads.] The cover must have a cast in legend "CP TEST."

2.3.1.2 Post Top Mounted

NEMA ICS 6. Metallic or non-metallic with terminal board, [5] [8] [_____] terminal posts and lockable lid. A non-metallic enclosure must be high impact strength molded plastic. The unit must be of standard design, manufactured for use as a CP test station, complete with cover, terminal board, shunts, and brass or Type [304] [316] stainless steel hardware. The terminal board must be removable for easy access to wires. The test station must be mounted atop 1830 mm 6 foot long polyethylene conduit with anchor. Terminal connections will be permanently tagged to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, and reference electrodes).

2.3.1.3 Wall Mounted

NEMA ICS 6, Type [3R] [4X] [_____] enclosure with [clamped cover] [Type [304] [316] stainless steel hinges and [clamped] [latched] cover] [and padlocked hasp]. Enclosure will be of [galvanized steel] [painted steel] [aluminum] [fiberglass] [non-metallic] construction with terminal board and labeled with nameplate. Provide nameplate in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM. Enclosure mounting posts must be [galvanized steel pipe, schedule [40] [80] [_____]], [wood post, full length pressure treated with pentachlorophenol] [as indicated]. Mount enclosure 1066 mm 42 inches above finished grade [as indicated]. Terminal connections will be permanently tagged to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, and reference electrodes).

2.3.1.4 IR-Free Test Station

[flush] [post top] [wall] mounted test station must include coupon of the same material as the structure, [shunt], [permanent reference electrode] with means of momentary isolation of the coupon with provided circuitry designed, manufactured and procured exclusively for CP instant-off testing of a cathodically-protected structure. Must be waterproof if used in flush test stations.

2.3.2 Shunts for Test Stations and 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 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 wire type.

2.3.3 Junction Box Enclosures

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.

2.3.3.1 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.

2.3.4 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).

2.3.5 Anode Junction Boxes

2.3.5.1 Enclosure

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 and labeled with nameplate. Provide nameplate in accordance with Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.

2.3.5.2 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, and reference electrodes).

2.4 MATERIALS

2.4.1 Impressed Current 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: Options for anode materials include "High-Silicon Chromium Bearing Cast Iron," "Graphite," and "Mixed Metal Oxide Coated" anodes. Selection of material must be based upon the conditions and operating parameters for the intended use. Precious metal or other anode materials, packaging or connections may also be appropriate for use, as determined by the engineer. These materials, packaging, or connections must also be submitted for approval in accordance with "Submittals Procedures."

****

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

Cast-iron anodes must be of the size indicated and conform to the following requirements:

2.4.1.2.1 Chemical Composition (Nominal)

ASTM A518/A518M, Grade 3. Chemical composition as follows:

Carbon	0.70 to 1.10 percent
Manganese	1.5 percent maximum
Silicon	14.20-14.75 percent
Chromium	3.25 to 5.00 percent
Copper	0.50 percent maximum
Molybdenum	0.20 percent maximum
Iron	Remainder

Anode dimensions: [_____] mm by [_____] inches. [Centrifugally cast tubular anodes with uniform wall thickness, [_____] mm by [_____] inches outer diameter, [_____] mm by [_____] inches square meter feet surface area, and [_____] kb [_____] lb bare anode weight.]

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 0.00000733 centimeter per degree F

2.4.1.3 Graphite Anodes

****

NOTE: Maximum allowable current densities for anode surface area are as follows:
Seawater: 40.37 amps per square meter 3.75 amps per square foot,
Fresh water: 2.69 amps per square meter 0.25 amps per square foot,
Soil (anode placed in backfill): 10.76 amps per square meter 1.0 amps per square foot. Do not

exceed the Manufacturer's allowable current for the specific anodes procured.
****

2.4.1.3.1 Chemical Composition (Nominal)

Impregnant	6.5 percent maximum
Ash	1.5 percent maximum
Moisture and Volatiles	0.5 percent maximum
Water Soluble Matter	1.0 percent maximum
Graphite	Remainder

Anode dimensions: [_____] mm [_____] inches

Bare graphite anodes must have a maximum electrical resistivity of 0.0011 ohm-centimeter.

2.4.1.3.2 Physical Properties

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 0.00000733 centimeter per degree F

2.4.1.4 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.
****

2.4.1.4.1 Conductive Material

Titanium substrate coated with an inert, dimensionally stable, electrically conductive coating with average composition of a 50/50 atomic percent mixture of iridium and titanium oxides, with a small amount of tantalum and ruthenium, 0.002 ohm-centimeter maximum resistivity, 50 MPa 7.25 ksi minimum adhesion or bond strength, and capable of sustaining a current density of 50 MPa 7.25 ksi adhesion or bond strength, and capable of sustaining a current density of 100 ampere per square meter 10.764 square feet in an oxygen generating electrolyte at 66 degrees C 150 degrees F for 20 years. Sinter the mixed metal oxide coating to the titanium surface as to remain tightly bound to the surface when bent 180 degrees onto itself.

2.4.1.4.2 Anode Life Test

The anode wire material must sustain current densities of 100 ampere per square meter 10.764 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 sustains a current density of 10,000 ampere per square meter 10.764 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 be 125 mm 5 inch in length taken from the lot of wire that is to be used for the anode.

2.4.2   Wire and Cable

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

2.4.2.1   Anode Lead Wire

Anodes must have lead wires installed at the factory. Anode connecting wire must be No. [8] [_____] AWG stranded copper wire with type CP HMWP insulation, 2.8 mm 7/64 inch thick, 600 volt rating. Cable-to-anode contact resistance must be 0.003 ohms maximum. In the toughest of environments, use wire specified for deep anode lead wire.

****
NOTE: The double insulated fluorocopolymer cable is intended for use in very harsh environments such as deep anode bed installations where chlorine and hydrogen gases are generated. This cable can be installed directly in soil or submerged in fresh, brackish, or salt waters. The CP HMWP cable is also a direct buried and submersible type cable suitable for harsh environments, but not as quiet as durable as the double insulated cable would be in the toughest of environments.
****

2.4.2.2   Deep Anode Lead Wire

For deep anodes, each anode must have a separate, continuous wire extending from the anode to the junction box with individual shunts. No spliced connections will be permitted in deep anode cables. No spliced connections will be permitted in deep anode cables. Chlorine gas resistant cable and shield connecting wire must be No. 8 [_____] AWG, stranded copper wire with [an inner jacket of 1 mm 40 mils of Halar insulation covered by an outer jacket of 1.6 mm 65 mils CP HMWP insulation] [HMWPE protective jacketed cable with a fluorocopolymer inner or primary insulation], [Dual Extrusion HALAR/HMWPE] [Dual Extrusion Kynar (PVDF)] Direct Burial Cable insulation with 600-volt rating. Cable-to-anode contact resistance must be 0.02 ohms maximum. For ceramic coated anodes, anode connecting wires must have molded multi-seal solder connections.

2.4.2.3   Anode Header Cable

Anode header cable must be No. [4][2][_____] AWG stranded copper wire with type CP HMWP insulation, 2.8 mm 7/64 inch thick 600 volt rating. Anode Header Cable aboveground in conduit must be No. [4][2][_____] AWG stranded copper wire with type [THHN] [THWN] [PVC] [TW] [RHW] [polyethylene] [CP high molecular weight insulation, 2.8 mm 7/64 inch thick][polyethylene] insulation, 600 volt rating.

2.4.2.4   Structure (Negative) Cable

Structure connecting wire must be No. [4] [2] [_____] AWG stranded copper wire with type [THHN] [THWN] [PVC] [TW] [RHW] [polyethylene] [CP high molecular weight insulation, 2.8 mm 7/64 inch thick] [polyethylene] insulation, 600 volt rating. Copper conductors conforming to ASTM B3 and ASTM B8.

2.4.2.5   Test Wires

Test wires must be No. 12 AWG stranded copper wire with NFPA 70 Type TW or RHW or polyethylene insulation. Copper conductors conforming to ASTM B3 and ASTM B8.

2.4.2.6   Joint and Continuity Bond Cables

Provide bonds across joints or any electrically discontinuous connections in the piping, and other pipes and structures with other than welded or threaded joints included in this CP system. Unless otherwise specified, bonds between structures and across joints in pipe with other than welded or threaded joints must be with No. 4 AWG stranded copper cable with polyethylene insulation. Bonds between structures must contain sufficient slack for any anticipated movement between structures. Bonds across pipe joints must contain a minimum of 100 mm 4 inch of slack to allow for pipe movement and soil stress. Bonds must be attached by exothermic welding. Exothermic weld areas must be insulated with coating compound and approved by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Continuity bonds must be installed as necessary to reduce stray current interference. Additional joint bonding must be done where determined during construction or testing or as directed. Joint bonding must include excavation and backfilling. There must be a minimum of 2 continuity bonds between each structure and other than welded or threaded joints. Electrical continuity must be tested across joints with other than welded or threaded joints and across metallic portions of sewage lift stations and water booster stations. Copper conductors conforming to ASTM B3 and ASTM B8.

2.4.2.7   Resistance Bond Wires

Resistance bonds must be adjusted for minimum interference while achieving the criteria of protection. Alternate methods may be used when approved.

2.4.2.8   AC Power Supply Wiring

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

2.4.2.9   Polyethylene Insulation

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

2.4.2.9.1   HMWPE

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

2.4.2.9.2 High Density Polyethylene (HDPE)

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

2.4.2.10 Rectifier DC Negative (Structure) Cable(s)

ASTM D1248 HMWPE insulation, stranded copper conductors, gauge (AWG) as indicated.

2.4.3 Cable and Wire Identification Tags

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

2.4.4 Anode Connection

****

NOTE: Type RHW-2-USE-2 insulation must be used under hot asphalt.

****

2.4.4.1 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.

2.4.4.2 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.

2.4.4.3 Canister Contained Anodes

Canister contained anodes are to be packed at the factory in sheet metal canisters with calcined petroleum coke breeze. The coke must have a resistivity of 0.1 ohm-cm tested at 1034 kPa 150 psi. The coke must be 11244 kg/cubic meter 70 lbs/cubic foot or greater. The maximum particle size must be 1 mm 0.039 inch and the coke dust-free. The canisters must be capped with tight fitting end caps secured to the body of the canister. The canister must provide a minimum annular space of 75 mm 3 inch all around the anode. The connecting cable needs to pass through a hole in an end cap designed to be tight fitting with the cable and protected from sharp edges with a plastic or rubber grommet. The anodes must be centered in the canisters and the annular space filled with coke breeze compacted in place.

2.4.5 Coke Breeze

2.4.5.1 Calcined Petroleum Coke Breeze (Dry)

Coke Breeze must conform to the following requirements:

2.4.5.1.1 Electrical Resistivity

Resistivity is not to exceed 1 milliohm-meter (0.1 ohm-cm) Great Lake Carbon C 12 A Test Method.

2.4.5.1.2 General Backfill Specifications

Bulk Density - 1044 to 1204 kg/cubic meter 65 to 75 lbs/cubic foot
Fixed Carbon - 99.0 percent or greater
Volatiles - 0.2 percent or less
Sizing - 100 percent less than 13 mm 1/2 inch

2.4.5.2 Metallurgical Coke Breeze (Processed)

Coke Breeze must conform to the following requirements:

2.4.5.2.1 Electrical Resistivity (Nominal)

Nominal electrical resistivity must be:

a. 100 milliohm-meter (10 ohm-centimeter) Max., tightly compacted.

b. 100 milliohm-meter to 150 milliohm-meter, (10 to 15 ohm-centimeter,) lightly compacted.

c. 150 to 200 milliohm-meter, (15 to 20 ohm-centimeter,) loose.

2.4.5.2.2 General Backfill Specifications

Bulk density - 608 to 672 kg per cubic meter 38 to 42 pounds per cubic foot
Fixed Carbon - 80 percent or greater
Sizing - 100 percent less than .10 mm 3/8 inch

2.4.6 Permanent Reference Electrodes

Permanent reference electrodes must be [copper/copper-sulfate] [silver silver-chloride] [zinc] [Hydrocarbon-Proof Palladium ($Pd/PdCl_2$)] specifically manufactured for [underground] [submersible] [_____] use, [32] [_____] mm [1 1/4] [_____] inch diameter, by [203] [255] [_____] mm [8] [10] [_____] inches long, [plastic [_____] tube with an ion trap to minimize contamination of the electrode] [, and 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. [The electrode will be prepackaged by the manufacturer with a backfill material as recommended by the manufacturer.] Provide electrodes with No. [10] [12] [_____] AWG, [RHW] [THHN] [_____] cable of sufficient length to extend to the [test station] [junction box] [rectifier] without splicing. 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 PRE 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.

****

2.4.7 Pavement Inserts

Pavement insert must be a non-metallic flush type test station without terminal board, and must allow a copper/copper sulfate reference electrode to contact the electrolyte beneath the pavement surface. [Provide traffic valve box capable of withstanding [H-20] [_____] traffic loads.]

2.4.8 Coupons

Coupons must match the material of the structure, with [1] [2] integrated connection(s) with electrical wire(s) and be designed, manufactured and procured for use as a corrosion coupon, IR-Free reference electrode, or AC reading electrode.

2.4.9 Zinc Grounding Cells

Two Zinc [Type II] [Type I] anodes separated with 24.5 mm 1 inch isolating spacers. Minimum 10 feet of #6 AWG HMWPE CP cable crimped securely to each anode. Both anodes centered in one cloth bag and surrounded with low resistance backfill mixture consists of 75 percent hydrated gypsum, 20 percent bentonite, and 5 percent sodium sulfate.

Element	**Content Percent**	
	MIL-A-18001 ASTM B418 Type I	**ASTM B418 Type II**
Al	0.1 - 0.5 percent	0.005 percent max
Cd	0.02 - 0.07 percent	0.003 percent max
Fe	0.005 percent max	0.0014 percent max
Pb	0.006 percent max	0.003 percent max
Cu	0.005 percent max	0.002 percent max
Zinc	Remainder	Remainder

Bare Weight		Width		Height		Length		Total Packaged Weight	
kg	pounds	mm	inches	mm	inches	mm	inches	kg	pounds
2.3	5	36	1.4	36	1.4	254	10	9.1	20
5.4	12	36	1.4	36	1.4	610	24	18.1	40
6.8	15	36	1.4	36	1.4	762	30	22.7	50
6.8	15	51	2.0	51	2.0	381	15	16.3	36
8.2	18	36	1.4	36	1.4	914	36	24.9	55
13.6	30	36	1.4	36	1.4	1524	60	39.0	86
13.6	30	51	2.0	51	2.0	762	30	30.4	67
20.4	45	51	2.0	51	2.0	1143	45	45.4	100
27.2	60	51	2.0	51	2.0	1524	60	54.4	120

2.5 ACCESSORIES

2.5.1 Wire Connectors

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

2.5.2 Electrical Tape

Pressure-sensitive vinyl plastic electrical tape must conform to UL 510.

2.5.3 Cable Marker Tape

Traceable marker tape must be manufactured for the purpose and clearly labeled "Cathodic Protection Cable Buried Below".

2.5.4 Insulating Tape

Pressure-sensitive vinyl plastic electrical tape and rubber insulated tape must conform to UL 510.

2.5.5 Underground Splices

Provide splices with a compression connector on the conductors, and insulation and waterproofing using one of the following methods which are suitable for continuous submersion in water and comply with ANSI C119.1.

2.5.5.1 Cast-Type Splice

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.

2.5.5.2 Gravity-Poured Splice

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.

2.5.5.3 Heat Shrinkable Splice

Provide [heavy wall] heat shrinkable splice insulation by means of a thermoplastic adhesive sealant material which must be applied by a clean burning propane gas torch.

2.5.6 Buried Cable Warning and Identification Tape

Polyethylene tape, manufactured for warning and identification of buried cable and conduit. Tape must be [75] [_____] mm [3] [_____] inches wide, [Yellow] [_____] in color and read "CAUTION CATHODIC PROTECTION CABLE BURIED BELOW". Color and lettering must be permanent and unaffected by moisture or other substances in backfill materials.

2.5.7 Conduit

[UL 6, rigid galvanized steel], [Outlet boxes: UL 514A and fittings UL 514B, threaded hubs]. [Metallic conduit and fittings to be PVC coated in accordance with NEMA RN 1, Type A40], [NEMA TC 2, Type EPC-40-PVC]. Non-metallic conduit must conform to NEMA TC 2.

2.5.8 Resistance Wire

Resistance wire must be AWG No. [16 or No. 22] [_____] nickel-chromium wire.

2.5.9 Deep Anode Bed Casing

****

NOTE: A metal casing must not be used except for a maximum of 1.5 meter 5 feet at the top for a well cap which also serves as a support for the suspension ropes. The drilling mud on the sides of the hole will usually keep the hole open until the anodes and coke breeze are installed. If a casing must be used, it must be fiberglass reinforced plastic (non-metallic) and must be located above the anode string.

****

Casing must be [_____] mm inch outside diameter, 3 mm 1/8 inch minimum wall thickness black steel pipe, conforming to ASTM A53/A53M, Type E or S, Grade B. The top casing must be [_____] mm inch outside diameter, 3 mm 1/8 inch minimum wall thickness black steel pipe, conforming to ASTM A53/A53M, Type E or S, Grade B. The metal casing must extend no more than [1.5] [_____] m [5] [_____] feet below the top of a well cap.

2.5.10 Anode Centering Device for Deep Anodes

Anode centering device must be metallic and capable of maintaining centering in the hole without interfering with other anode lead wiring, until coke breeze is packed in place. Centering device must have mechanical means of firmly attaching to vent pipe and anode.

2.5.11 Vent Pipes

All deep anodes must be vented in anode zones. Openings in the vent must not be larger than 0.1524 mm 0.006 inch.

2.5.12 Sealing and Dielectric Compound

Sealing and dielectric compound must be a black, rubber-based compound that is soft, permanently pliable, tacky, moldable, and unbacked. Apply compound as recommended by the manufacturer, but not less than 3 mm 1/8 inch thick.

2.5.13 Protective Coating

Except as otherwise specified, protective coating for underground metallic components including pipe and fittings must be applied mechanically in a factory or field plant specially equipped for the purpose. Valves and fittings that cannot be coated mechanically must have the protective coating applied by hand, preferably at the plant. Joints must be coated by hand. Hand coating must produce a coating equal in thickness to the coating applied mechanically. Piping and components installed in valve boxes or manholes must also receive the specified protective coating.

2.5.13.1 Pipeline Metallic Components

Underground metallic pipelines and structures must have a good quality factory-applied coating. This includes carbon steel, cast iron and ductile-iron pipelines or vessels. If non-metallic pipelines are installed, metallic fittings or pipe sections must be coated as follows.

a. The nominal thickness of the metallic pipe joint or other component coating must be [0.2] [0.4] [0.6] [1.0] [1.5] [_____] mm [8] [16] [24] [40] [60] [_____] mils, plus or minus 5 percent.

b. Pipe and joint coating for factory-applied or field-repair material must be applied as recommended by the manufacturer and must be one of the following:

(1) Fusion bonded epoxy.

(2) Continuously-extruded polyethylene and adhesive coating system.

(3) Polyvinyl chloride pressure-sensitive adhesive tape.

(4) High-density polyethylene/bituminous rubber compound tape.

(5) Butyl rubber tape.

(6) Coal tar epoxy.

2.5.13.2 Field Joints

Coat field joints with material compatible with the existing pipeline coating compound. Apply the joint coating material to an equal thickness as the pipeline coating. Unbonded coatings must not be used on buried metallic piping. This prohibition includes unbonded wraps or tubes.

2.5.14 Preformed Sheaths

Preformed sheaths for encapsulating electrical wire splices to be buried underground must fit the insulated wires entering the spliced joint.

2.5.15 Epoxy Potting Compound

Epoxy potting compound for encapsulating electrical wire splices to be buried underground must be a two package system made for the purpose.

2.5.16 Backfill Shields

Backfill shields must consist of approved pipeline wrapping or fiberglass reinforced, coal-tar impregnated tape, or plastic weld caps, specifically made for the purpose.

2.5.17 Isolation Flange Sets/Kits

****

NOTE: On projects having piping installed by Division 2, SITEWORK or Division 15, MECHANICAL, coordinate the requirements for flanges and unions with the appropriate section(s).

****

Provide full-faced gaskets, isolating sleeves and washers, and steel washers. Provide isolation flange kits rated for operation at the rated pressure and temperature. Bolts must be replaced with similar type longer bolts if less than two threads extend beyond the end of both steel washers.

2.5.18 Dielectric Unions

****

NOTE: On projects having piping installed by Division 2, SITEWORK or Division 15, MECHANICAL, coordinate the requirements for flanges and unions with the appropriate section(s).

****

ASME B16.39, Class [1] [2] rated for dimensional, strength, and pressure requirements. Insulation barrier must limit galvanic current to one percent of the short-circuit current in a corresponding metallic joint. Provide insulating material impervious to [water] [oil] [gas].

2.5.19 Electrical Isolation of Structures

Isolating fittings, including isolating flanges and couplings, must be installed above ground or in a concrete hand hole. As a minimum, isolating flanges or unions must be provided at the following locations:

a. Connection of new piping to existing pipes.

b. Pressure piping under floor slab to a building.

c. Additionally, isolation must be provided between new pipe lines and foreign pipes that cross the new lines within 3 m 10 feet.

2.5.19.1   Gaskets

****
NOTE: Do not use asbestos materials.
****

ASME B16.21. [Neoprene faced phenolic] [Laminated phenolic] material for operation at [_____] KPa, [232] [_____] degrees C [_____] psi, [450] [_____] degrees F. Asbestos materials must not be used.

2.5.19.2   Isolation Washers and Sleeves

Two sets 3 mm 1/8 inch [laminated phenolic] [_____] for operation at [232] [_____] degrees C [450] [_____] degrees F. Isolating washers must fit within the bolt facing on the flange over the outside of the fabric reinforced phenolic sleeve.

2.5.20   Electrically Isolating Pipe Joints

****
NOTE: The CP system will fail unless full consideration is given to specifications for electrically isolating pipe joints, electrically conductive pipe joints, and casing cradles and seals. Mechanical and electrical specifications must reference this paragraph and paragraph "Electrically Conductive Couplings."
****

Electrically isolating pipe joints for above- or below-ground use must be [flexible, mechanical pipe couplings of an electrically isolating type consisting of bolted or compression design provided with electrically isolating joint harness if required to provide pull-out strength] [flexible, integral electrically isolating pipe couplings designed for field installation by means of a swaging system and providing pull-out strength with a factor of safety] [nonflexible flanged type electrically isolating pipe joints to be field assembled] [nonflexible factory assembled electrically isolating pipe joints designed with stub ends for installation by welding and providing pull-out strength with a factor of safety].

2.5.20.1   Threaded Fittings

Threaded type electrically isolating pipe joints must have molded plastic screw threads and be used above ground only. Machined plastic screw threads must not be used.

2.5.21   Electrically Conductive Couplings

Electrically conductive couplings must be of a type that is in regular factory production.

2.5.22   Stray Current Measurements

Perform stray current measurements as indicated. Alternate methods may be used when approved. The stray current test report must indicate location of test, type of pipes tested, method of testing, [_____].

2.5.23 Cast-In-Place 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].

2.5.24 Isolation and End Seals

2.5.24.1 Casing Isolator/Centralizer

[High density (linear), injection molded virgin Polyethylene] [Polycarbonate Hi-Temp isolators/spacers rated for service at least 280 degrees F. (138 degrees C) or more] [High Grade Thermoplastic] positive electrical isolation, high abrasion resistance and low coefficient of friction.

2.5.24.2 End Seals

Ethylene Propylene Diene Monomer (EPDM) Neoprene rubber end seals, thickness of 1/8 inch or more, with [2] [4] Stainless Steel Pipe Clamps per end seal, 1/8 inch thick and 1/2 inch wide or more.

2.5.25 Steel Flanges and Bolting

2.5.25.1 Steel Flanges

ASME B16.5, [668 N] [1335 N] [150 lb.] [300 lb.].

2.5.25.2 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.

2.5.26 Gravel

100 percent to pass a 25 mm 1 inch mesh.

2.5.27 Casing Isolation and Seals

Exothermic weld kits specifically designed by the manufacturer for exothermic welding wires to metallic surfaces. Molds must be for specific type of metallic structure (steel, cast iron), specific diameter of pipe or metallic surface and specific size (AWG)and type of wire (solid, stranded).

PART 3 EXECUTION

3.1 SAFETY PRECAUTIONS AND HAZARDOUS LOCATIONS

Any personnel performing operations that will generate heat, sparks, or flame in hazardous locations must first perform adequate safety precautions. A trained responsible person must ensure the area is safe to perform the operation. Required actions include ensuring adequate ventilation before work starts, air monitoring, and a fire watch must be provided and remain for 30 minutes after the operation is completed. A minimum of a 20 pound ABC type fire extinguisher must be available and must be inspected before each use. Equipment being used must be inspected and used in accordance with manufacturer recommendations. Combustibles that are in the work area(s) must be moved or if they cannot be moved, be covered with fire retardant welding blankets. When performing exothermic welding, properly sized charges and inspection of the structure condition must be accomplished to ensure a safe operation.

3.2 INSTALLATION

3.2.1 Anode Bed Installation

IEEE C2NFPA 70 Anode configuration and size must be as indicated in design drawings. A minimum of [one] [two] [three] [ten] [15] [_____] anodes must be installed in locations as specified in design drawings. Materials must meet these specifications. The corrosion expert must verify that the materials are in accordance with the approved submittals. Anode beds must be installed in remote earth or distributed around the structure being protected.

3.2.1.1 Shallow Anode Beds

Shallow ground beds must contain size and quantity of anodes designed to meet the design current requirement of the CP system at an initial operating current output density not exceeding [40] [50] [70] percent of manufacturers recommended current output density of the specific anodes being installed.

3.2.1.1.1 Horizontally Buried Bare Anodes

Horizontally buried bare anodes must be bedded on and covered with coke breeze as specified in a trench excavated for the purpose at depths, spacing and locations as shown in design drawings. Anodes must be completely surrounded by the backfill at bottom, sides, and top for a distance of not less than 100 mm 4 inch. Backfill must be compacted.

3.2.1.1.2 Vertically Buried Bare Anodes

Vertically buried bare anodes must be installed in vertical holes in the ground having a depth, spacing, and location shown. The holes in the ground must be sufficiently large to provide an annular space around the anode not less than 100 mm 4 inch. The anodes must be centered in the hole and backfilled with coke breeze. Backfill must be compacted.

3.2.1.1.3 Horizontally Buried Canister-Contained Anodes

Horizontally buried canister-contained anodes must be buried in a trench excavated for the purpose at depths, spacing, and locations shown.

3.2.1.1.4 Vertically Buried Canister-Contained Anodes

Vertically buried canister-contained anodes must be installed in vertical holes in the ground having depth, spacing, and locations shown. The holes in the ground must be sufficiently larger in diameter than the canisters to facilitate easy lowering into the hole and backfilling. The space between the canister and the wall of the hole must be completely backfilled with a wet slurry of earth free of stones.

3.2.2   Remote Anode Systems

Remote anode systems must consist of groups of anodes connected in parallel to a header cable, buried in the ground at depths, spacing, and locations shown. The anodes must be buried [horizontally] [vertically].

3.2.3   Distributed Anode Systems

Distributed anode systems must consist of a line or row of anodes connected in parallel to a header cable and buried in remote earth at depths, spacing, and locations shown. The anodes must be buried [horizontally] [vertically].

3.2.4   Linear Anode ICCP Systems

These systems are commonly used to protect long line structures, such as pipelines. This is usually the most economical choice when the pipeline due to poor or aged coating requires a continuous and close coupled current. This type of anode bed is used to protect pipelines with poor coating and can be installed up to several miles along a pipeline. The distance from the structure is normally 5 to 10 feet (1.5 to 3 meters). In most cases, the anode is installed with a separate header cable to minimize voltage drop. Mixed metal oxide anodes or polymer anodes are typically used for this type of installation.

3.2.5   Deep Anode Lead Wire

Each anode must have a separate, continuous lead wire, without splices, from the anode and terminating in an aboveground junction box equipped with individual anode current shunts.

3.2.5.1   Anode Centering

Anodes must be centered in the well by means of centering devices.

3.2.5.2   Casing

The casing must be to a depth and elevation indicated in design drawings.

3.2.6   Backfill

Backfill the well with specified coke breeze or metallurgical coke breeze surrounding the anodes by a method that does not leave voids or bridging. The recommended method is to pump the backfill from the bottom upward. The well must be over-filled with coke breeze allowing for settlement so that the settled level after a number of days is as high as the level shown. The number of days allowed for settling of the coke breeze will be determined by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. If the top level of coke breeze is below the level shown after settlement, put additional coke breeze in the well. The backfill used must not require tamping. The top portion of the well must be sealed for 8 m 25 feet to prevent surface water run-off. All vents must be vented above the high water mark and at a safe height.

3.2.7   Cable Marker Tape

Locate traceable marker tape in the same trench above CP cables including structure leads, anode leads, anode header cables, test station leads, bonding cables, and rectifier electrical power cables.

3.3 MISCELLANEOUS INSTALLATION

3.3.1 Rectifier Installation

Mounting must be as shown. [Pole or wall mounting must be equipped with a channel bracket, lifting eyes, and a keyhole at the top.] [Cross-arm brackets must accommodate a 102 by 102 mm 4 by 4 inch cross-arm.]

3.3.2 Test Stations

Provide test stations complete with an insulated terminal block having the indicated number of terminals; provided with a lockable cover and have a cast-in legend, "C.P. Test" and complete with an insulated terminal block having the required number of terminals. (One terminal required for each conductor). Provide sufficient test stations to monitor underground isolation points. Test-bond stations (potential measurement and stray current control) must be provided to monitor pipe-to-soil potential of proposed underground pipes or existing underground metallic structures which may conduct stray current from the new CP system. The location of the test-bond stations must ensure that the pipe-to-soil potential of metallic pipe not designated to be protected is not made less negative by the energization of the CP system. Test station terminal connections and the terminal conductor must be permanently tagged to identify each termination of the conductors (e.g. identify the conductors connected to the protected structures). Conductors must be permanently identified in the station by means of plastic or metal tags, or plastic sleeves to indicate termination. Each conductor must be color coded in accordance with the drawings. The station test facility, including permanent copper/copper-sulfate reference electrodes and test returns must be installed as indicated. Pavement inserts must be non-metallic and must allow copper/copper-sulfate reference electrode to contact the electrolyte beneath the pavement surface. Abbreviations must not be used. Welding of electrical connections must be as follows: Exothermic welds must be as specified. Use and selection of these materials and welding equipment must be in accordance with the manufacturer's recommendations.

3.3.3 Permanent Reference Electrodes

3.3.3.1 Permanent Reference Electrode Verification

Verify permanent reference electrodes against a calibrated 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. Permanent electrode must measure a reference potential agreeing with that measured by the portable electrode within plus or minus 0.010 volts when the sensing windows of the two electrodes being compared are not more than 2 mm 1/6 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.

3.3.4 Bonding Boxes

Provide structure bonding boxes in locations [as indicated] [where the protected structure crosses or comes into close proximity to other metal structures that are unprotected or protected by its own electrically isolated CP system(s)].

3.3.5 Joint Bonds

Provide joint bonds on metallic pipe to and across buried flexible couplings, mechanical joints, flanged joints [except at places where isolation joints are specified] and joints not welded or threaded to provide electrical continuity. Connect bond wire(s) to the structure(s) by use of exothermic weld kit(s). Clean the structure surface by scraping, filing or wire brushing to produce a clean, bright surface. [Weld connections using exothermic kits in accordance with the kit manufacturer's instructions.] Check and verify adherence of the bond to the substrate for mechanical integrity by striking the weld with a 908 gram 2 pound hammer. Cover connections with an electrically insulating coating [which is compatible with the existing coating on the structure].

3.3.6 Casings, Isolation, and Seals

Where a pipeline is installed in a casing under a roadway or railway, the pipeline must be electrically isolated from the casing, and the annular space sealed against incursion of water.

3.3.7 Wire Connections

3.3.7.1 Wire-To-Structure Connections

Lead wire to structure connections must be by exothermic welding process. Weld charges made specifically for use on cast iron must be used on cast iron pipe. A backfill shield filled with a pipeline mastic sealant or material compatible with the coating must be placed over the weld connection and must cover the exposed metal adequately. If other methods of connection are required, they must be approved by the corrosion expert and the Contract Officer or the Contracting Officer's Representative.

3.3.7.2 Cable Protection

Positive cable to the ground bed and negative cable to the [pipe] [tank] to be protected must be buried a minimum depth of 750 mm 30 inch except where above ground construction utilizing conduit is used.

3.3.7.3 Wire Splicing

Connecting wire splicing must be made with copper compression connectors or exothermic welds, following instructions of the manufacturer. Split-bolt type connectors must not be used.

3.3.8 Steel Surfaces

Connections to [ferrous pipe] [metal tanks] must be made by exothermic weld methods as manufactured by an approved manufacturer for the type of [pipe] [tank]. If other methods of connection are required, such as brazing, mechanical, electric-arc welding and other types of welded connections to ferrous pipe and structures, they must be approved by the corrosion expert and the Contracting Officer or the Contracting Officer's Representative before use.

3.3.9 Pipe Joints

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NOTE: This paragraph will be coordinated with and referenced in mechanical and electrical specifications.
****

3.3.10 Electrical Continuity

Underground pipe must be electrically continuous except at places where electrically isolating joints are specified. Pipe joined by means other than welding must meet the following electrical continuity requirements:

a. Mechanical joints that are not factory designed to provide electrical continuity must be bonded by installing a metallic bond across the joint. The bonding connections must be made by the exothermic welding process.

b. Mechanical joints designed to provide electrical continuity may be used.

3.3.11 Electrical Isolation of Structures

Perform electrical isolation of structures as follows:

3.3.11.1 Gas Distribution Piping

Provide electrical isolation at each building riser pipe to the pressure regulator, both swivels on the pressure regulator, at all points where a short circuit to another structure or to a foreign structure may occur, and at other locations as indicated.

3.3.11.2 Locations of Electrical Isolation

[a. Steam piping

][b. High-temperature-water piping

][c. Chilled-water piping

][d. Line conduits

][e. Fuel-storage tanks

][f. Gasoline-storage tanks

][g. Fire-suppression tanks

]

Provide electrical isolation at each building entrance, and at other locations as indicated.

3.3.11.3 Copper Piping

Copper piping must be [electrically isolated at both ends of the pipe run] [coated with an approved coating and electrically isolated at both ends].

3.3.11.4 Underground Storage Tanks (UST)

Electrically isolate tanks from other metallic structures. Bond components protected with the tank such as pipes, vents, anchors, and fill pipes to the tank.

3.3.11.5 Dissimilar-Metals

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NOTE: This paragraph will be coordinated with and referenced in mechanical and electrical specifications.
****

Buried piping of dissimilar metals including new and old steel piping, excepting valves, must be electrically separated by means of electrically isolating joints at every place of connection. The isolation joint, including the pipes, must be coated with an underground type dielectric coating for a minimum distance of 10 diameters on each side of the joint.

3.3.12 Ferrous Valves

Dissimilar ferrous valves in a buried ferrous pipeline, including the pipe, must be coated with an underground type dielectric coating for a minimum distance of 10 diameters on each side of the valve.

3.3.13 Brass or Bronze Valves

Brass or bronze valves must not be used in a buried ferrous pipeline.

3.3.14 Metal Pipe Junction

If the dissimilar metal pipe junction, including valves, is not buried and is exposed to atmosphere only, the connection or valve, including the pipe, must be coated with an underground type dielectric coating for a minimum distance of 3 diameters on each side of the junction.

3.4 INSTALLATION DETAILS

3.4.1 Anode Installation

Unless otherwise authorized, installation must not proceed without the presence of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Anodes of the size specified must be installed to the depth indicated and at the locations shown. Locations may be changed to clear obstructions with the approval of the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Anodes will be installed in sufficient number and of the required type, size, and spacing to obtain a uniform current distribution over the surface of the structure. The anode system will be designed for a life of 25 years of continuous operation. Anodes must be installed as indicated in a dry condition after any plastic or waterproof protective covering has been completely removed from the water permeable, permanent container housing the anode metal. The anode connecting wire must not be used for lowering the anode into the hole. The annular space around the anode must be backfilled with fine earth in 150 mm 6 inch layers and each layer must be hand tamped.

3.4.2 Underground Pipe Joint Bonds

Underground pipe having other than welded or threaded coupling joints must be made electrically continuous by means of a bonding connection installed across the joint.

3.4.3 Anode Junction Boxes

Provide junction boxes and mark each of the wires terminating in each box.

3.4.4 Bonding Boxes

Provide structure bonding boxes in locations [as indicated] [where the protected structure crosses or comes into close proximity to other metal structures that are unprotected or protected by its own electrically isolated CP system(s)].

3.4.5 Test Stations and Permanent Reference Electrodes

Test stations will be of the type and location shown and will be [curb box] [post] [wall] mounted. Provide buried isolation joints with test wire connections brought to a test station. Reference all test stations with GPS coordinates. Unless otherwise shown, locate other test stations [and permanent reference electrodes] [as indicated.] as follows:

a. At [305] [_____] meters [1000] [_____] foot intervals.

b. At all isolation joints.

c. At both ends of casings.

d. Where the pipe crosses any other metal pipes.

e. Where the pipe connects to an existing piping system.

f. Where the pipe connects to a dissimilar metal pipe.

Do not fill the bottom of the test station with concrete unless otherwise specified. Do not place rubbish, scrap or other debris into the test station.

3.4.6 Permanent Reference Electrode Calibration and Installation

Calibrate 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. Calibrate in a test tank containing 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 0.005 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 reference electrodes as well.

3.4.6.1 Field Drawings

Complete a field drawing of [each anode installation showing location of anode, depth of anode, color and size of anode lead wire and any other pertinent details] [test station location and diagram] [Underground Pipe Joint bond locations and details] [Anode Junction Box Location and details] [Bonding Box location and details] [Permanent Reference Electrode locations] [Location of all Electrical Isolations]. Submit copy with daily report to the government.

3.5 ELECTRICAL ISOLATION OF STRUCTURES

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NOTE: The CP system will fail unless full engineering considerations are applied to selection, location and installation of electrically conductive joints and electrically isolating joints including the use of underground type dielectric coatings (not paint). Adequate electrical conductivity of a pipe joint made by means other than welding must be determined by a "corrosion expert." Allowable electrical resistance depends on the cross sectional area of the pipe metal, the resistivity of the pipe metal, and the effectiveness of the coating on the pipe. Factors to be considered include:

a. Deflection stresses.

b. Pull-out stresses.

c. Expansion-contraction due to temperature changes.

d. Is function as a union necessary?

e. Is field assembly of critical parts practical?

f. Hazardous locations to be avoided.

g. Accessibility if above ground.

h. Location of test box if below ground.

i. Importance of coating the adjacent structure if below ground.

j. Vulnerability to short circuiting.

Factor of safety on pull-out strength required has to be engineered for the specific conditions involved since no blanket provisions are fully applicable to all cases. The requirement for isolating flanges or couplings must be based on a study of the conditions. If the new piping is a short extension to an existing old piping system not under CP, an isolating fitting must be installed at the point of connection, since the new piping will be anodic to the older system. If the older system is under CP, no isolating fitting must be used.

****

3.5.1 Isolation Fittings

Isolating fittings, including isolating flange kits, dielectric unions and couplings, must be installed aboveground, or within manholes, wherever possible. Where isolating joints must be covered with soil, they must be fitted with a proper joint cover specifically manufactured for covering the particular joint, and the space within the cover filled with hot coal-tar enamel. Isolating fittings in lines entering buildings must be located at least 305 mm 12 inch above grade of floor level, when possible. Isolating joints must be provided with grounding cells to protect against over-voltage surges or approved surge protection devices. The cells must provide a low resistance across isolating joint without excessive loss of cathodic current.

3.5.2 Dielectric Unions

[Cut pipe ends square, remove fins and burrs, cut taper pipe threads in accordance with ASME B1.20.1.] Provide isolation unions as indicated. Work piping into place without springing or forcing. Apply joint compound or thread tape to male threads only. Backing off to permit alignment of threaded joints will not be permitted. Engage threads so that not more than three threads remain exposed. [Cover unions with an electrically insulating coating.]

3.5.3 Gas Distribution Piping

Electrical isolation will be provided at each building riser pipe to the pressure regulator, on both swivels on the pressure regulator, at all points where a short to another structure or to a foreign structure may occur, and at other locations as indicated on the drawings. If an isolating joint is located inside a vault, the pipe must be sleeved with insulator when entering and leaving the vault.

3.5.4 Joint Bonds

Provide joint bonds on metallic pipe to and across buried flexible couplings, mechanical joints, flanged joints [except at places where isolation joints are specified] and joints not welded or threaded to provide electrical continuity. Connect bond wire(s) to the structure(s) by use of exothermic weld kit(s). Clean the structure surface by scraping, filing or wire brushing to produce a clean, bright surface. [Weld connections using exothermic kits in accordance with the kit manufacturer's instructions.] Check and verify adherence of the bond to the substrate for mechanical integrity by striking the weld with a 908 gram 2 pound hammer. Cover connections with an electrically insulating coating [which is compatible with the existing coating on the structure].

3.5.5 Casings, Isolation, and Seals

Where the pipeline is installed in a casing under a roadway or railway, isolate the pipeline from the casing, and seal the annular space against intrusion of water.

3.6 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 initial field test report submission.

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 days 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.
****

3.6.1 Tests and Measurements

3.6.1.1 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 [backfilling of the pipe] [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 [pipe [and casings]] [structure]. Perform measurements at anode junction boxes, test stations and other locations suitable for test purposes (such as service risers or valves), at intervals not exceeding [30] [120] [_____] meters [100] [400] [_____] feet [with readings at each end point and the midpoints as a minimum]. 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.

3.6.1.2 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 Project Manager corrosion expert 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. [For underground storage tanks, take a minimum of three measurements with the reference electrode located as follows: Directly over the longitudinal and transverse centerlines of the tank at intervals not exceeding the diameter of the tank and to a distance from the tank of two times the tank diameter.] 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 contractor's expense, deficiencies in the materials and installation observed by these tests and inspections.

3.6.1.3 Isolation Testing

Before the anode system is connected to the [pipe] [tank], an isolation test must be made at each isolating joint or fitting. This test will demonstrate that no metallic contact, or short circuit exists between the two isolated sections of the [pipe] [tank]. Any isolating fittings installed and found to be defective must be reported to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager.

3.6.1.4 Isolation Tester

An isolation tester designed and manufactured for use in CP, using the continuity check circuit, must be used for all isolating joint (flange) electrical testing. Testing must conform to the manufacturer's operating instructions. Test must be witnessed by the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. An isolating joint that is good will read full scale on the meter. If an isolating joint is shorted, the meter pointer will be deflected or near zero on the meter scale. Location of the fault will be determined from the instructions, and the joint must be repaired.

3.6.1.5 Anode Output

As the anodes or groups of anodes are connected to the [pipe] [tank] [_____], current output will be measured with an approved clamp-on milliammeter, calibrated shunt with a suitable millivoltmeter or multimeter, or a low resistance ammeter. (Of the three methods, the low-resistance ammeter is the least desirable and most inaccurate. The clamp-on milliammeter is the most accurate.) The values obtained and the date, time, and location must be recorded.

3.6.1.6 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 over any length of line or component. Additional measurements will be made at each distribution service riser, with the reference electrode placed directly over the service line.

3.6.1.7 Casing Tests

Before final acceptance of the installation, the electrical isolation of carrier pipe from casings must be tested and any short circuits corrected.

3.6.1.8 Holiday Test

Any damage to the protective coating during transit and handling must be repaired before installation. After field-coating has been applied, the entire pipe must be inspected by an electric holiday detector with Impressed Current in accordance with NACE SP0188 using a full-ring, spring-type coil electrode. 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 covering 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.

3.6.1.9 Rectifier Testing

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.

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NOTE: The voltage should not exceed a negative polarized potential of 1.200 volts (1200 millivolts). This could result in excessive current being applied to the structure which could cause coating disbondment.

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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.

3.6.1.10 Stray Current Measurements

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NOTE: Stray current may effect foreign pipelines or other metallic structures.

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Before final acceptance of the installation, stray current tests must be performed on any foreign [pipes] [tanks][other metallic structures] in close proximity to the installed anodes. A full report of the tests giving all details must be made.

3.6.1.11 Induced AC Testing

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NOTE: Induced AC may affect pipelines or other metallic structures when near high AC voltage infrastructure. Reference NACE SP0177 and NACE SP21424.

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Before final acceptance of the installation, induced AC voltage tests must be performed on the [pipes] [tanks] [other metallic structures] near high AC voltage infrastructure and where crossing above ground and underground AC transmission systems. A full report of these tests must be included in the final testing reports with all details and data taken. The touch potential of any testing over 5 volts must be reported to the Contracting Officer or the Contracting Officer's Representative, Technical Expert and Project Manager. Any touch potential over 10 Volts must be mitigated by effective mitigation techniques.

3.6.1.12 Interference Tests

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NOTE: Interference from other structures' CP current may adversely affect the structure and the structure CP current may adversely affect other metallic structures.

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Before final acceptance of the installation, interference tests will be made with respect to any foreign [pipes] [tanks] in cooperation with the owner of the foreign [pipes] [tanks]. A full report of the tests giving all details must be made. Stray current measurements must be performed at all isolating locations and at locations where the new pipeline crosses foreign metallic pipes; results of stray current measurements must also be submitted for approval. The method of measurements and locations of measurements must be submitted for approval. As a minimum, stray current measurements must be performed at the following locations:

a. Connection points of new pipeline to existing pipeline.

b. Crossing points of new pipeline with other existing metallic pipelines.

3.6.1.13 Initial Cathodic Protection System Field 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 and rectifier testing.

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NOTE: Additional testing may be required based upon the specific project or design. Other tests may include isolation testing, casing testing, permanent reference electrode testing, stray current testing, interference testing, and induced AC testing.

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The contractor must submit an initial field test report of the CP system. All structure-to-electrolyte measurements, including native potentials, protected potentials, anode current testing, rectifier testing, 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.

3.6.1.14 Government Field Testing

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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.

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The government corrosion [engineer] [program manager] must review the contractor's initial field 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 not to 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" and "Final Field Testing."

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3.6.1.15 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].

3.6.1.16 Final Acceptance Field Testing

Conduct final field testing of the CP system utilizing the same procedures specified under, "Initial Field Testing of the Galvanic Cathodic Protection 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 Field 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 of anodes and wires 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 since it is estimated that no section of pipeline must remain uncovered for more than two (2) days. 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 not be less than 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.

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

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NOTE: There are restrictions on the type and extent of training. Training is usually on-site, 2 days or less. Contractor Representative or designee will provide basic instructions to facility maintenance and operation personnel. If more extensive training is required, e.g., student travel, special consultants, consult the Contract Division Director and the head of the Comptroller Department for assistance.

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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 not less than [two] [four] [_____] hour[s] and not more than [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 --