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USACE / NAVFAC / AFCESA / NASA **UFGS-26 42 17.00 10 (November 2008)**

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

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2012
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SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 42 17.00 10

CATHODIC PROTECTION SYSTEM (IMPRESSED CURRENT)

11/08

-- End of Section Table of Contents --

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SECTION 26 42 17.00 10

CATHODIC PROTECTION SYSTEM (IMPRESSED CURRENT)
11/08

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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 items(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 should be submitted as a Criteria Change Request (CCR).

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PART 1 GENERAL

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 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.

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2012) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM B418	(2009) Standard Specification for Cast and Wrought Galvanic Zinc Anodes
ASTM B843	(2007) Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
ASTM D1248	(2012) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 81	(1983) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE C135.30	(1988) Standard for Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction

NACE INTERNATIONAL (NACE)

NACE RP0193	(2001) External Cathodic Protection of On-Grade Carbon Steel Storage Tank Bottoms
NACE SP0169	(1992; R 2007) Control of External Corrosion on Underground or Submerged Metallic Piping Systems
NACE SP0188	(1999; R 2006) Discontinuity (Holiday) Testing of New Protective Coatings on Conductive Substrates
NACE SP0572	(2001; R 2007) Design, Installation, Operation and Maintenance of Impressed Current Deep Anode Beds

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C80.1	(2005) American National Standard for Electrical Rigid Steel Conduit (ERSC)

NEMA TC 2	(2003) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2011; Errata 2 2012) National Electrical Code

U.S. NATIONAL ARCHIVES AND RECORDS ADMINISTRATION (NARA)

40 CFR 280	Technical Standards and Corrective Action Requirements for Owners and Operators of Underground Storage Tanks (UST)
49 CFR 192	Transportation of Natural and Other Gas by Pipeline: Minimum Federal Safety Standards
49 CFR 195	Transportation of Hazardous Liquids by Pipeline

UNDERWRITERS LABORATORIES (UL)

UL 467	(2007) Grounding and Bonding Equipment
UL 506	(2008; Reprint Mar 2010) Specialty Transformers
UL 510	(2005; Reprint Apr 2008) Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2004; Reprint Apr 2010) Metallic Outlet Boxes
UL 6	(2007; reprint Nov 2010) Electrical Rigid Metal Conduit-Steel

1.2 SYSTEM DESCRIPTION

Submit proof that the materials and equipment furnished under this section conform to the specified requirements contained in the referenced standards or publications. The label or listing by the specified agency will be acceptable evidence of such compliance.

1.2.1 General Requirements

a. Provide a complete, operating impressed current cathodic protection system in accordance with NFPA 70, the applicable federal, state and local regulations, and the requirements of this contract. In addition to the minimum requirements of these specifications, [construction of gas pipelines and associated cathodic protection systems shall be in compliance with 49 CFR 192] [and] [construction of hazardous liquid pipelines, and associated cathodic protection system shall be in compliance with 49 CFR 195] [and] [construction and installation of underground fuel storage tanks and associated cathodic protection system shall be in compliance with 40 CFR 280].

b. The system includes planning, inspecting the installation, adjusting and testing cathodic protection and test system using rectifiers and impressed current anodes, supplemented with sacrificial anodes as needed, for utilities and equipment shown. The cathodic protection system shall also include cables, connectors, splices, corrosion protection test stations, ace power panels, and any other equipment required for a complete operating system providing the specified protection. The cathodic protection system includes (a) calculations for rectifier, anodes, and any recommendations for supplementing or changing the minimum design criteria to provide the specified potentials and (b) equipment, wiring, and wiring devices necessary to produce a continuous flow of direct current from anodes in the soil electrolyte to the pipe surfaces.

c. Submit [6] [_____] 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 stating the maximum recommended anode current output density and the rate of gaseous production, if any, at that current density. Detail drawings shall contain complete wiring and schematic diagrams and any other details required to demonstrate that the system has been coordinated and will function properly as a unit. The installation shall meet the specified protection criteria for a 25 year life.

d. Submit [6] [_____] copies of operating manual outlining the step-by-step procedures required for system startup, operation, adjustment of current flow, and shutdown. The manuals shall include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and their basic operating features.

e Submit [6] [_____] copies of maintenance manual listing routine maintenance procedures, recommendation for maintenance testing, possible breakdowns and repairs, and troubleshooting guides. The manuals shall include single line diagrams for the system as installed; instructions in making [pipe-] [tank-] to-reference cell potential measurements and frequency of monitoring; instructions for dielectric connections, interference and sacrificial anode bonds; instructions shall include precautions to ensure safe conditions during repair of pipe system.

1.2.2 Contractor's Modifications

The specified system is based on an impressed current system supplemented with magnesium anodes. The Contractor may modify the cathodic protection system after review of the project, site verification and analysis if the proposed modifications include the impressed current anodes and rectifiers and will provide better overall system performance.

a. Submit [6] [_____] copies of detail drawings showing proposed changes in location, scope or performance indicating any variations from, additions to, or clarifications of contract drawings. The drawings shall 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 each pipe, and any other pertinent information to the proper installation and performance of the system.

b. The modifications shall be fully described, shall be approved by the Contracting Officer and shall meet the following criteria. The proposed system shall achieve a minimum pipe-to-soil "Instant Off" potential of minus 850 millivolts with reference to a saturated copper-copper sulfate reference cell on the underground metallic components of the [piping] [tanks] [_____].

c. Take resistivity measurements of the soil in the vicinity of the [pipes] [tanks] [_____] and ground bed sites; based upon the measurements taken, adjust current and voltage of the rectifier as required to produce a minimum of minus 850 millivolts "Instant Off" potential between the structure being tested and the reference cell. This potential shall be obtained over 95 percent of the metallic area without the "Instant Off" potential exceeding 1200 millivolts.

d. Submit final report regarding supplemental magnesium anode installation. The report shall include pipe-to-soil measurements throughout the affected area, indicating that the additions corrected the conditions which made the additional anodes necessary, and current measurements for the additional anodes. The following special materials and information are required: Calculations on current and voltage for [100 V] [40 V] [_____] rectifier plus rectifier and meter specifications; taping materials and conductors; zinc grounding cell, installation and testing procedures, and equipment; coating material; system design calculations for rectifier, anode number, life, and parameters to achieve protective potential; backfill shield material and installation details showing waterproofing; bonding and waterproofing details; insulated resistance wire; exothermic weld equipment and material.

1.3 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list to reflect only the submittals required for the project.

The Guide Specification technical editors have designated 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 submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy, Air Force, and NASA projects.

Choose the first bracketed item for Navy, Air Force and NASA projects, or choose the second bracketed item for Army projects.
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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for [Contractor Quality Control approval.] [information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

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

SD-03 Product Data

Miscellaneous Materials[; G][; G, [_____]]
Spare Parts

SD-06 Test Reports

Tests and Measurements
Contractor's Modifications[; G][; G, [_____]]

SD-07 Certificates

Tests and Measurements
Cathodic Protection System
Services of "Corrosion Expert"[; G][; G, [_____]]

SD-10 Operation and Maintenance Data

Cathodic Protection System
Training Course

1.4 QUALITY ASSURANCE

1.4.1 Services of "Corrosion Expert"

Obtain the services of a "corrosion expert" to supervise, inspect, and test the installation and performance of the cathodic protection system. "Corrosion expert" refers to a person, who, by reason of 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 metallic piping and tank systems.

a. Such a person shall be accredited or certified by the National Association of Corrosion Engineers (NACE) as a NACE Accredited Corrosion Specialist or a NACE certified Cathodic Protection (CP) Specialist or be a registered professional engineer who has certification or licensing that includes education and experience in corrosion control of buried or submerged metallic piping and tank systems, if such certification or licensing includes 5 years experience in corrosion control on underground metallic surfaces of the type under this contract.

b. Submit the "corrosion expert's" name and qualifications certified in writing to the Contracting Officer prior to the start of construction, including 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.

c. The "corrosion expert" shall make at least 3 visits to the project site. The first of these visits shall include obtaining soil resistivity data, acknowledging the type of pipeline coatings to be used and reporting to the Contractor the type of cathodic protection required. Once the submittals are approved and the materials delivered, the "corrosion expert" shall revisit the site to ensure the Contractor understands installation practices and laying out the components. The third visit shall involve testing the installed cathodic protection systems and training applicable personnel on proper maintenance techniques. The "corrosion expert" shall supervise installation and testing of all cathodic protection.

1.4.2 Isolators

Isolators are required to isolate the indicated pipes from any other structure. Isolators shall be provided with lightning protection and a test station as shown.

1.4.3 Anodes and Bond Wires

Install anodes in sufficient number and of the required type, size and spacing to obtain a uniform current distribution of 2.5 milliamperes per 0.09 square meters square foot minimum to underground metal surfaces. For each cathodic protection system, the metallic components and structures to be protected shall be made electrically continuous. This shall be accomplished 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. Provisions shall be included to return stray current to its source without damaging structures intercepting the stray current. The electrical isolation of underground facilities in accordance with acceptable industry practice shall be included under this section.

1.4.4 Surge Protection

Install approved zinc grounding cells or sealed weatherproof lightning arrestor devices across insulated flanges or fittings installed in underground piping as indicated on the drawings. The arrestor shall be gapless, self-healing, solid state type. Zinc anode composition shall conform to ASTM B418, Type II. Lead wires shall be number 6 AWG copper with high molecular weight polyethylene (HMWPE) insulation. The zinc grounding cells shall not be prepackaged in backfill but shall be installed as detailed on the drawings. Lightning arrestors or zinc grounding cells are not required for insulated flanges on metallic components used on nonmetallic piping systems.

1.4.5 Sacrificial Anodes

Locate sacrificial high potential magnesium anodes as required to provide localized cathodic protection or supplemental cathodic protection for the impressed current system. Each sacrificial magnesium anode shall be routed through a test station. The magnesium anode shall not be connected to the pipe.

1.4.6 Nonmetallic Pipe Systems

When nonmetallic pipe is approved, direct buried or submerged metallic components of the pipe system shall have cathodic protection. Metallic components are connectors, tees, fire hydrants, valves, short pipes, elbows, tie rods, or other metallic equipment. As a minimum, each metallic component shall be protected with a 4.1 kg 9 lb magnesium anode connected through a test station. The use of nonmetallic pipe does not change other requirements of the specifications such as submittals, testing, or design calculations for each metallic component. Deviations due to the use of nonmetallic pipe shall be approved by the Contracting Officer.

1.4.6.1 Coatings

Coatings for metallic components shall be as required for metallic fittings. Protective covering (coating and taping) shall be completed and tested on each metallic component and shall be as required for underground metallic pipe. Mechanical joints and fittings of either the electrically conductive or insulating type shall be coated with an underground type dielectric coating system. Where external electrical continuity bonds are installed across mechanical joints, bare or exposed metal, welds, bare wire and exposed coupling parts shall be coated with a coating system.

a. Couplings and fittings which have a low profile exterior designed to permit tape coating shall be primed and wrapped with an underground type pipe tape system or two-part epoxy system.

b. Couplings and fittings that cannot be properly taped shall be enclosed in a [spaced mold manufactured for the purpose] [shroud of reinforced kraft paper] and filled with [cold applied dielectric compound] [hot applied bituminous compound not exceeding 135 degrees C 275 degrees F in application temperature].

1.4.6.2 Tracer Wire

When a nonmetallic pipe line is used to extend or add to an existing metallic line, an insulated No. 8 AWG copper wire shall be connected to a terminal in a test station located at each point of transition from metallic pipe to nonmetallic pipe. At each of these test stations, the tracer wire terminal shall be strapped or bonded to the terminal for the negative connection wire to the existing metallic line. The tracer wire shall be run the length of the new nonmetallic line. This wire shall be used as a locator tracer wire and to maintain continuity to any future extension of the pipe line.

1.5 DELIVERY, STORAGE, AND HANDLING

Storage for magnesium anodes will be designated by the Contracting Officer. If anodes are not stored in a building, protect them from inclement weather. Packaged anodes damaged as result of improper handling or weather exposure shall be resacked and the required backfill added.

1.6 EXTRA MATERIALS

Submit spare parts data for each different item of material and equipment specified, after approval of detail drawings and not later than [_____]

months prior to the date of beneficial occupancy. Include in the data a complete list of parts, special tools, and supplies, with current unit prices and source of supply. Furnish one spare anode of each type.

PART 2 PRODUCTS

2.1 IMPRESSED CURRENT ANODES

2.1.1 Bare High Silicon Cast-Iron Anodes

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

2.1.1.1 Chemical Composition (Nominal)

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

2.1.1.2 Electrical Resistivity

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

2.1.1.3 Physical Properties (Nominal)

Tensile strength	103.4 MPa
Compressive strength	689.5 MPa
Brinell hardness	520
Density	7000 kilograms per cubic meter
Melting point	1260 degrees C
Coefficient of expansion from 0 to 100 degree C	132 nanometer per degree C

Tensile strength	15,000 psi
Compressive strength	100,000 psi
Brinell hardness	520
Density	7.0 grams per cubic centimeter
Melting point	2300 degrees F
Coefficient of expansion from 32 to 212 degrees F	0.00000733 centimeter per degree F

2.1.2 Bare Graphite Anodes

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

2.1.3 Canister Contained Anodes

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

2.1.4 Anode Connecting Cables

Anodes shall have connecting cables installed at the factory. For deep ground beds, each anode located in the borehole shall be accompanied by a reel of continuous cable having the length indicated. No spliced connections will be permitted in deep well cables.

2.1.5 Mixed Metal Oxide Anodes

Mixed metal oxide anodes shall be of the size indicated and shall conform to the following requirements.

2.1.5.1 Conductive Material

The electrically conductive coating shall contain a mixture consisting primarily of iridium, tantalum, and titanium oxides. The average composition is generally a 50/50 atomic percent mixture of iridium and titanium oxides, with a small amount of tantalum. The resistivity, as tested by the manufacturer, shall be no more than 0.002 ohm-centimeter, and the bond strength shall be greater than 50 MPa 7.25 ksi to guarantee the current capacity life and the quality of the conductive ceramic coating. The adhesion or bond strength shall be determined by epoxy bonding a 2.54 mm 0.1 inch diameter stud to the ceramic coating and measuring the load to failure (about 70 MPa 10.15 ksi) of either the epoxy or the interface between the coating and the substrate. The anode must be inert and the electrically conductive ceramic coating dimensionally stable. The ceramic coated anode shall be 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, to ensure the current capacity life. An accelerated current capacity life test shall be performed by the manufacturer on every lot of anode wire used to construct the anode as described. The mixed metal oxide coating shall be applied to the wire anode by a firm that is regularly engaged in and has a minimum 5 years experience in manufacturing and applying mixed metal oxide coatings to titanium anode substrates. The mixed metal oxide must be sintered to the titanium surface as to remain tightly bound to the surface when bent 180 degrees onto itself.

2.1.5.2 Anode Life Test

The anode wire material shall sustain current densities of 100 ampere per square meter 10.764 square feet in an oxygen generating electrolyte for 20 years. The manufacturer shall 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 shall be powered with a constant current power supply for the 30 day test period. The representative sample shall be 125 mm 5 inch in length taken from the lot of wire that is to be used for the anode.

2.1.5.3 Canister Contained Mixed Metal Oxide Anodes

Canister contained mixed metal oxide anodes shall be packed at the factory in light weight, light gauge steel uni-body TIG welded canisters with calcinated petroleum coke breeze. The canisters shall be capped with TIG welded steel and caps providing a totally encapsulated construction. The connecting cable shall pass through a hole in an end cap designed to be tight fitting with a heavy duty strain relief allowing for handling of the canister by the cable. The anode shall be centered in the canister by centralizers to maintain rod position.

2.1.5.4 Anode Connecting Cables

Anodes shall have connecting cables installed at the factory. The connection between the anode rod or ribbon and the lead wire shall be made with a solid crimp couple with solder. The connection shall be sealed in cast epoxy.

2.1.5.5 Canister Connection Cables

Canister connecting cables shall consist of an ultra low resistance solder connection which is a minimum of three times stronger than the cable. For ceramic coated canister anodes, the cable connection shall consist of two molded dielectric layers (pressure seals), a flexible backfill resin encapsulant stabilizer, a schedule 40 PVC pipe Type 1 seal, and Type 1 PVC pipe end plugs. The seals and end plugs shall resist chlorine gas and acid.

2.1.5.6 Deep Anode Connection Cables

For deep anode beds, each anode located in the borehole shall be accompanied by a reel of continuous cable having the length indicated. For deep ceramic coated anode beds, anode connecting cables shall have molded multiseal solder connections; splices will not be permitted. Chlorine gas resistant cable and shield shall be used for chlorine environments.

2.2 RECTIFIERS AND ASSOCIATED EQUIPMENT

2.2.1 Rectifier Unit

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NOTE: Air-cooled rectifiers will be used for most applications. Where highly corrosive atmospheres exist, the equipment will be oil-immersed in a tank-type housing. For hazardous area applications, oil-immersed equipment will be provided with an explosion-proof or dust-ignition-proof housing, as appropriate. Transformer tap adjusters will be provided in cases where an automatic system is not provided.

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Rectifier unit shall consist of a transformer, rectifying elements, transformer tap adjuster, terminal block, [one dc output voltmeter, one dc output ammeter,] [one combination volt-ammeter,] one toggle switch for each meter, fuse holders with fuses for each dc circuit, variable resistors, an ac power-supply circuit breaker, lightning arresters for both input and output, all wired and assembled in a weatherproof cabinet. The overall efficiency of the rectifier shall be not less than 65 percent when operated at nameplate rating and shall 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 in excess of 10 years.

2.2.1.1 Transformer

Transformer shall conform to UL 506.

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

2.2.1.3 Meters

Meters shall be accurate to within plus or minus 2 percent of full scale at 27 degrees C 80 degrees F, and shall possess temperature stability above and below 27 degrees C 80 degrees F and shall possess temperature stability above and below 27 degrees C 80 degrees F of at least 1 percent per 5 degrees C 10 degrees F. Separate meters shall be 63.5 mm 2-1/2 inch nominal size or larger.

2.2.1.4 Circuit Breaker

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

2.2.1.5 Fuses

Cartridge-type fuses with suitable fuse holders shall be provided in each leg of the dc circuit.

2.2.2 Cabinet Construction

Cabinet shall be constructed of [not lighter than 1.56 mm 16 gauge [steel] [hot dipped galvanized steel] [stainless steel] [aluminum]] [molded fiberglass reinforced polyester], and shall be provided with a full door. The enclosure shall have oil-resistant gasket. The door shall be hinged and have a hasp that will permit the use of a padlock. The cabinet shall 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 shall be conveniently located.

2.2.2.1 Wiring Diagram

A complete wiring diagram of the power unit showing both the ac supply and the dc connections to anodes shall be on the inside of the cabinet door. All components shall be shown and labeled.

2.2.2.2 Grounding Provisions

Grounding provisions shall [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 shall be solid or stranded copper not smaller than No. 6 AWG. The earth grounding system shall consist of one or more ground rods. Ground rods shall 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 shall be driven full length into the earth. Sectional type rods may be used.

2.2.2.3 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 shall be measured using the fall-of-potential method described in IEEE 81. The maximum resistance of driven ground shall not exceed 25 ohms under normally dry conditions. If this resistance cannot be obtained with a single rod, [_____] additional rods not less than 1.8 m 6 feet on centers, or if sectional type rods are used, [_____] additional 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, the Contracting Officer shall be notified immediately. Connections below grade shall be fusion welded. Connections above grade shall be fusion welded or shall use UL 467 approved connectors.

2.2.2.4 Cabinet Paint System

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

2.2.3 Wiring

Wiring shall be installed in accordance with NFPA 70 utilizing type TW or RHW or polyethylene insulation. Fittings for conduit and cable work shall conform to UL 514A. Outlets shall be of the threaded hub type with gasketed covers. Conduit shall be hub type with gasketed covers. Conduit shall be securely fastened at 2.4 m 8 foot intervals or less. Splices shall be made in outlet fittings only. Conductors shall be color coded for identification. Cable for anode header and distribution shall be No. [2] [_____] AWG stranded copper wire with type [cathodic protection high molecular weight polyethylene] [Dular/Halar] insulation.

2.2.4 Oil Immersed Enclosures

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NOTE: The enclosure should not be used in areas

prone to flooding unless required for hazardous locations. Provisions should be made for flooding.
****

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

2.3 COKE BREEZE

2.3.1 Calcined Petroleum Coke Breeze (Dry)

Breeze shall conform to the following requirements:

2.3.1.1 Electrical Resistivity

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

2.3.1.2 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

2.3.2 Metallurgical Coke Breeze (Processed)

Breeze shall conform to the following requirements:

2.3.2.1 Electrical Resistivity (Nominal)

Nominal electrical resistivity shall 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.

2.3.2.2 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 MISCELLANEOUS MATERIALS

Within [30] [45] [_____] days after receipt of notice to proceed, submit an itemized list of equipment and materials including item number, quantity, and manufacturer of each item. The list shall be accompanied by a description of procedures for each type of testing and adjustment, including testing of coating for thickness and holidays. Installation of materials and equipment shall not commence until this submittal is approved.

2.4.1 Electrical Wire

2.4.1.1 Anode Connecting Wire

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

****

Anode connecting wire shall be No. [8] [_____] AWG stranded copper wire with type CP high molecular weight polyethylene insulation, 2.8 mm 7/64 inch thick, 600 volt rating. Cable-to-anode contact resistance shall be 0.003 ohms maximum. Deep anode ground bed connecting wire shall 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 high molecular weight polyethylene insulation, 600 volt rating. Cable-to-anode contact resistance shall be 0.02 ohms maximum.

2.4.1.2 Anode Header Cable

****

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 high molecular weight polyethylene cable is also a direct buried and submergible type cable suitable for harsh environments, but not as quiet as durable as the double insulated cable would be in the toughest of environments.

****

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

2.4.1.3 Test Wires

Test wires shall be No. 12 AWG stranded copper wire with NFPA 70 Type TW or RHW or polyethylene insulation.

2.4.1.4 Resistance Wire

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

2.4.2 Deep Anode Ground Bed Casing

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NOTE: A metal casing should 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 should be fiberglass reinforced plastic (nonmetallic) and should be located above the anode string.
****

Casing shall 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 shall 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 shall extend no more than [1.5] [_____] m [5] [_____] feet below the top of a well cap.

2.4.3 Anode Centering Device for Deep Anode Ground Beds

Anode centering device shall be nonmetallic and capable of maintaining centering in the hole without interfering with other anode lead wiring, until coke breeze is packed in place.

2.4.4 Conduit

Nonmetallic conduit shall conform to NEMA TC 2.

2.4.5 Test Boxes and Junction Boxes

Boxes shall be outdoor type conforming to UL 514A.

2.4.6 Vent Pipes

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

2.4.7 Polyethylene Insulation

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

2.4.7.1 High Molecular Weight Polyethylene

High molecular weight polyethylene shall be Type I, Class C, Grade E5.

2.4.7.2 High Density Polyethylene

High density polyethylene shall be Type III, Class C, Grade E3.

2.4.8 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) shall 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 cathodic protection system. The location of the test-bond stations shall 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 cathodic protection system. Test station terminal connections and the terminal conductor shall be permanently tagged to identify each termination of the conductors (e.g. identify the conductors connected to the protected structures). Conductors shall be permanently identified in the station by means of plastic or metal tags, or plastic sleeves to indicate termination. Each conductor shall be color coded in accordance with the drawings. The station test facility, including permanent Cu-Cu S04 reference cells and test returns shall be installed as indicated. Pavement inserts shall be nonmetallic and shall allow Cu-Cu S04 reference electrode to contact the electrolyte beneath the pavement surface. Abbreviations shall not be used. Welding of electrical connections shall be as follows: Exothermic welds shall be "CADweld", "Thermo-weld", or approved equal. Use and selection of these materials and welding equipment shall be in accordance with the manufacturer's recommendations.

2.4.9 Calibrated Shunts

Install shunts calibrated in current per potential (e.g. mA/V) between the lead or header wire connected to the anode and the current collector lead connected to the structure. The calibration of the shunt shall be clearly marked and installed to be visible.

2.4.10 Sealing and Dielectric Compound

Sealing and dielectric compound shall 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.

2.4.11 Protective Covering

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

2.4.11.1 Pipeline Metallic Components

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

a. The nominal thickness of the metallic pipe joint or other component coating shall 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 shall be applied as recommended by the manufacturer and shall 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.

2.4.11.2 Field Joints

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

2.4.11.3 Inspection of Pipe Coatings

Once the pipeline or vessel is set in the trench, conduct an inspection of the coating including electrical holiday detection as described in paragraph TESTS AND MEASUREMENTS.

2.4.11.4 Above Ground Piping System

Above ground piping shall be given two coats of exterior oil paint. Surface preparation shall be as recommended by paint manufacturer, except as follows: ferrous, shop primed surfaces shall be touched up with ferrous metal primer; surfaces that have not been shop primed shall be solvent cleaned; surfaces that contain loose rust, mil scale, or other foreign substances shall be mechanically cleaned by power wire brushing and primed with ferrous metal primer; and primed surfaces shall be finished with two coats of exterior oil paint or vinyl paint.

2.4.12 Preformed Sheaths

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

2.4.13 Epoxy Potting Compound

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

2.4.14 Backfill Shields

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

2.4.15 Electrical Tape

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

2.4.16 Cable Marker Tape

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

2.4.17 Electrically Isolating Pipe Joints

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NOTE: The cathodic protection 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 should reference this paragraph and paragraph "Electrically Conductive Couplings."

****

Electrically isolating pipe joints for above or below ground use shall 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].

2.4.17.1 Threaded Fittings

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

2.4.17.2 Electrically Isolating Pipe Joints

Electrically isolating pipe joints shall be of a type that is in regular factory production.

2.4.18 Electrically Conductive Couplings

Electrically conductive couplings shall be of a type that has a published maximum electrical resistance rating given in the manufacturer's literature. Cradles and seals shall be of a type that is in regular factory production made for the purpose of electrically isolating the carrier pipe from the casing and preventing the incursion of water into the annular space.

2.4.19 Joint and Continuity Bonds

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 cathodic protection system. Unless otherwise specified, bonds between structures and across joints in pipe with other than welded or threaded joints shall be with No. 4 AWG stranded copper cable with polyethylene insulation. Bonds between structures shall contain sufficient slack for any anticipated movement between structures. Bonds across pipe joints shall contain a minimum of 100 mm 4 inch of slack to allow for pipe movement and soil stress. Bonds shall be attached by exothermic welding. Exothermic weld areas shall be insulated with coating compound and approved by the Contracting Officer. Continuity bonds shall be installed as necessary to reduce stray current interference. Additional joint bonding shall be done where determined during construction or testing or as directed. Joint bonding shall include excavation and backfilling. There shall be a minimum of 2 continuity bonds between each structure and other than welded or threaded joints. Electrical continuity shall be tested across joints with other than welded or threaded joints and across metallic portions of sewage lift stations and water booster stations.

2.4.19.1 Resistance Bonds

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

2.4.19.2 Stray Current Measurements

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

2.4.20 Electrical Isolation of Structures

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

a. Connection of new piping to existing pipes.

b. Pressure piping under floor slab to a building.

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

2.5 MAGNESIUM ANODES

Weights and dimensions of magnesium anodes shall be approximately as follows:

TYPICAL MAGNESIUM ANODE SIZES
(Cross sections may be round, square, or D shaped)

NOMINAL WT. kg.	APPROX. SIZE (mm)	NOMINAL GROSS WT kg PACKAGED IN BACKFILL	NOMINAL PACKAGE DIMENSIONS (mm)
1.4	76 X 76 X 127	3.6	133 X 133 X 203
2.3	76 X 76 X 203	5.9	133 X 133 X 286
4.1	76 X 76 X 356	12.3	133 X 508
5.5	102 X 102 X 305	14.5	191 X 457
7.7	102 X 102 X 432	20.5	191 X 610
14.5	127 X 127 X 521	30.9	216 X 711
22.7	178 X 178 X 406	45.5	254 X 610

TYPICAL MAGNESIUM ANODE SIZES
(Cross sections may be round, square, or D shaped)

NOMINAL WT. LBS.	APPROX. SIZE (IN)	NOMINAL GROSS WT LBS PACKAGED IN BACKFILL	NOMINAL PACKAGE DIMENSIONS (IN)
3	3 X 3 X 5	8	5 1/4 X 5 1/4 X 8
5	3 X 3 X 8	13	5 1/4 X 5 1/4 X 11 1/4
9	3 X 3 X 14	27	5 1/4 X 20
12	4 X 4 X 12	32	7 1/2 X 18
17	4 X 4 X 17	45	7 1/2 X 24
32	5 X 5 X 20 1/2	68	8 1/2 X 28
50	7 X 7 X 16	100	10 X 24

2.5.1 Composition

Anode shall be of high potential magnesium alloy, made of primary magnesium obtained from sea water or brine, and not from scrap metal. Magnesium anodes shall conform to ASTM B843 and to the following analysis unless otherwise indicated:

Element	Percent by Weight
Aluminum	0.02 maximum
Manganese	1.50 maximum
Zinc	0.05
Silicon	0.10 maximum
Copper	0.02 maximum
Nickel	0.002 maximum
Iron	0.03 maximum
Impurities	0.30 maximum
Magnesium	Remainder

Furnish spectrographic analyses on samples from each heat or batch of anodes used on this project.

2.5.2 Packaged Anodes

Provide anodes in packaged form with the anode surrounded by specially prepared quick-wetting backfill and contained in a cloth or paper sack. Anodes shall be centered in the backfill material. The backfill material shall have the following composition, unless otherwise indicated.

Material	Percent by Weight
Gypsum	75
Bentonite	20
Sodium Sulfate	5

2.5.3 Lead Wires

Anode lead wires shall consist of No. 10 solid copper wire, with TW insulation. Lead wires shall be not less than 3 m 10 feet in length, without splices.

2.5.4 Connection Wires

Wires shall consist of No. 10 solid copper wire with RHW-USE or polyethylene insulation.

2.5.5 Insulation

Type RHW-USE insulation shall comply with NFPA 70. Polyethylene insulation shall comply with ASTM D1248; high molecular weight polyethylene shall be Type I, Class C, Grade E5; high density polyethylene shall be Type III, Class C, Grade E3.

2.5.6 Conduit Steel

Conduit steel shall conform to UL 6 and ANSI C80.1.

2.5.7 Tape

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

2.5.8 Backfill Shields

Provide shields consisting of approved wrapping of reinforced fiberglass coal-tar impregnated tape, or plastic weld caps specifically made for the purpose and installed in accordance with the manufacturer's recommendations. When joint bonds are required, due to the use of mechanical joints, the entire joint shall be protected with kraft paper joint cover. The joint cover shall be filled with poured hot coal-tar enamel.

2.5.9 Electrical Connections

Electrical connections shall be done as follows:

a. Exothermic welds shall be "Cadweld" or Burndy "Thermo-Weld" or approved equal. Use of these materials shall be in accordance with the manufacturer's recommendations.

b. Electrical shielded arc welds on steel pipe shall be approved via shop drawing action.

c. Other methods of welding shall be specifically approved for use by the pipe manufacturer.

2.5.10 Anode Installation

Anode configuration and size shall be as indicated. A minimum of [one] [two] [three] [ten] [15] [_____] anodes are required to achieve minus 850 millivolts "instant off" potential and shall be required on the [_____] components or structure. Details shown are indicative of the general type of material required and are not intended to restrict selection of materials or of any particular manufacturer. The anode system shall be designed for a life of 25 years of continuous operation.

2.6 LEAD WIRE CONNECTIONS

Lead wire to structure connections shall be by exothermic welding process. Weld charges made specifically for use on cast iron shall be used on cast iron pipe. A backfill shield filled with a pipeline mastic sealant or material compatible with the coating shall be placed over the weld connection and shall cover the exposed metal adequately.

PART 3 EXECUTION

3.1 CRITERIA OF PROTECTION

Acceptance criteria for determining the adequacy of protection on a buried [pipe] [tank] shall be in accordance with [NACE SP0169,] [and] [NACE RP0193,] and as specified below.

3.1.1 Iron and Steel

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NOTE: If the second method is used, the requirement for obtaining measurements over 95 percent of the entire metallic area is required as in the first method. Verification of the 100 millivolts decay of polarization should be achieved at points over 95 percent of the entire metallic area.
****

Use the following method a. for testing cathodic protection voltages. If more than one method is required, use method b.

a. A negative voltage of at least minus 850 millivolts as measured between the [pipe] [tank] [specified underground component] and a saturated copper-copper sulphate reference electrode contacting the (electrolyte) earth directly over the [pipe] [tank] [specified underground component]. Determination of this voltage shall be made with the cathodic protection system in operation. Voltage drops shall be considered for valid interpretation of this voltage measurement. A minimum of minus 850 millivolts "instant off" potential between the [structure] [pipe] [tank] [specified underground component] being tested and the reference cell shall be achieved over 95 percent of the area of the structure. Obtain adequate number of measurements over the entire structure, pipe, tank, or other metallic component to verify and record achievement of minus 850 millivolts "instant off". This potential shall be obtained over 95 percent of the total metallic area without the "instant off" potential exceeding 1200 millivolts.

b. A minimum polarization voltage shift of 100 millivolts as measured between the [pipe] [tank] and a saturated copper-copper sulphate reference electrode contacting the earth directly over the [pipe] [tank]. This polarization voltage shift shall be determined by interrupting the protective current and measuring the polarization decay. When the protective current is interrupted, an immediate voltage shift will occur. The voltage reading, after the immediate shift, shall be used as the base reading from which to measure polarization decay. Measurements achieving 100 millivolts shall be made over 95 percent of the metallic surface.

3.1.2 Aluminum

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

3.1.3 Copper Piping

For copper piping the following criteria shall 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 shall be determined as outlined for iron and steel.

3.2 GROUND BED INSTALLATION

3.2.1 Shallow Ground Beds

Shallow ground beds shall contain size and quantity of anodes designed to meet performance criteria of the cathodic protection system at an initial operating current output density not exceeding [40] [50] [70] percent of maximum recommended current output density.

3.2.1.1 Horizontally Buried Bare Anodes

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

3.2.1.2 Vertically Buried Bare Anodes

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

3.2.1.3 Horizontally Buried Canister-Contained Anodes

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

3.2.1.4 Vertically Buried Canister-Contained Anodes

Vertically buried canister-contained anodes shall be installed in vertical holes in the ground having depth, spacing, and locations shown. The holes in the ground shall 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 shall be completely backfilled with a wet slurry of earth free of stones.

3.2.1.5 Cable Protection

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

3.2.1.6 Multiple Anode Systems

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

3.2.1.7 Distributed Anode Systems

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

3.2.2 Deep Anode Ground Beds

Deep anode ground beds shall consist of an installation of anodes supported one above the other and supported in place by a method that does not suspend the anodes from the connecting cable. Deep anode ground beds shall be installed in accordance with NACE SP0572 and as specified in these specifications.

3.2.2.1 Anode Centering

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

3.2.2.2 Casing

The casing shall be to a depth and elevation of not more than [_____] m feet.

3.2.2.3 Casing Insulation

The portion of casing above the top anode shall be coated with an electrically insulating underground type coating.

3.2.2.4 Anode Requirements

Anode sizes, spacing, number of anodes, depth of well, and other details shall be as shown.

3.2.2.5 Anode Lead Wire

Each anode shall have a separate, continuous wire extending from the anode to the junction box at the well head.

3.2.2.6 Anode Cables

Anode cables shall terminate in a nearby junction box, equipped with individual anode current shunts. Where full length casing is used, two wire connections from casing shall terminate in the junction box.

3.2.2.7 Anode and Cable Installation

If the method of installation utilizes backfill support for anodes and cable, provide slack in the cable near each anode and increase the cable insulation in thickness from 2.8 to 4.0 mm 7/64 to 5/32 inch utilizing an approved composite of plastic and elastomeric materials.

3.2.2.8 Backfill

Backfill the well with calcined petroleum 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 shall 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. If the top level of coke breeze is below the level shown after settlement, put additional coke breeze in the well. The backfill used shall not require tamping. The top portion of the well shall be sealed for 8 m 25 feet to prevent surface water run-off. All vents shall be vented above the high water mark and at a safe height.

3.2.2.9 Cable Marker Tape

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

3.2.2.10 Pavement Inserts

Install pavement inserts at a minimum of 30 m 100 foot intervals for pipelines. The pavement inserts shall be installed directly over the structure being protected and tested.

3.3 MAGNESIUM ANODE INSTALLATION

Installation shall not proceed without the presence of the Contracting Officer, unless otherwise authorized. Anode locations may be changed to clear obstructions when approved. Install anodes in sufficient number and of the required type, size, and spacing to obtain a uniform current distribution surface on the structure. Prepackaged anodes shall be installed as shown on the drawings.

3.3.1 Installation of Packaged Anodes

Install packaged anodes completely dry, lower them into holes by rope sling or by grasping the cloth gather. The anode lead wire shall not be used in lowering the anodes. Backfill the hole with fine soil in 150 mm 6 inch layers and each layer shall be hand-tamped around the anode. The tamper shall not strike the anode or lead wire. If immediate testing is to be performed, add water only after backfilling and tamping has been completed to a point 150 mm 6 inch above the anode. Approximately 8 L 2 gallons of water shall be poured into the hole; after the water is absorbed by the soil, backfilling and tamping shall be completed to the top of the hole. Anodes shall be installed as shown. When rock is found prior to achieving specified depth, anode may be installed horizontally to a depth at least as deep as the bottom of the pipe, with the approval of the Contracting Officer.

3.3.2 Underground Metal Pipe Line

Install anodes 610 mm 2 feet below the line to be protected unless otherwise noted on the drawings. To facilitate periodic electrical measurements during the life of the sacrificial anode system and to reduce the output current of the anodes if required, anode lead wires in a single group of anodes shall be buried a minimum of 610 mm 2 feet and each anode lead wire shall be connected to an individual terminal in a test station. The anode lead cable shall make contact with the structure only through a test station. Resistance wire shall be installed between the anode lead cable and the pipe cable in the test station to reduce the current output, if required.

3.3.3 Lead and Resistance Wire Splices

Lead wire splicing, when necessary, shall be made with copper split bolt connectors of proper size. The joint shall be carefully wrapped with at least 3 layers of electrical tape. Resistance wire connections shall be done with silver solder and the solder joints wrapped with a minimum of 3 layers of pressure-sensitive tape.

3.3.4 Magnesium Anodes for Metallic Components

As a minimum, each metallic component shall be protected with [2] [_____] [4.1] [7.7] [_____] kg [9] [17] [_____] lb magnesium anodes located on each side of the metallic component and routed through a test station. Fire hydrant pipe component shall have a minimum of [2] [3] [_____] [4.1] [7.7] [_____] kg [9] [17] [_____] lb magnesium anodes routed through a test station for each hydrant. Pipe under concrete slab shall have a minimum of [5] [_____] [7.7] [_____] kg [17] [_____] lb anodes for each location where metal pipe enters the building under the slab. A permanent reference cell shall be provided adjacent to the pipe entrance to the slab. Conductors shall be routed to a test station. Each valve shall have a minimum of [2] [_____] [4.1] [_____] kg [9] [_____] lb magnesium anodes routed through a test station. Sections of metallic pipe 6.1 m 20 foot long, when used where force mains are within 3 m 10 feet of the water pipe, shall have a minimum of [4] [_____] 7.7 kg 17 lb anodes.

3.4 MISCELLANEOUS INSTALLATION

****

NOTE: The cathodic protection 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 should be determined by the "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. Effectively coated pipe underground requires only a fraction of the electrical conductivity at joints needed for bare pipe. Shop painted pipe is considered to be the same as bare pipe and is not to be confused with pipe coated with an underground type dielectric coating.

The type of electrical isolating pipe joint to be used requires engineering design consideration. In general, the dielectric parts of an isolating joint will not withstand structural or environmental

stresses as well as an all-metal type of joint. If the pipe on the cathodic protected side of the underground electrically isolating pipe joint, including the joint, is not effectively coated, interference type corrosion may occur unless other measures are taken. 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 pipe 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 should be based on a study of the conditions. If the new piping is a short extension to an existing old piping system not under cathodic protection, an isolating fitting should be installed at the point of connection, since the new piping will be anodic to the older system. If the older system is under cathodic protection, no isolating fitting should be used.
****

3.4.1 Rectifier Installation

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

3.4.2 Wire Connections

3.4.2.1 Wire Splicing

****
NOTE: In water tanks, split bolts are used (above the water line only) because working space is limited and the hydraulic or mechanical compression tools may be cumbersome and hazardous to use; since a single split-bolt will work loose when the wires

it connects are moved, a minimum of two split bolts should be used. At ground level or in trenches, compression tools can be used conveniently, and the swaged sleeve connection produced by such tools is more reliable than split bolts.
****

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

3.4.2.2 Steel Surfaces

Connections to [ferrous pipe] [metal tanks] shall be made by exothermic weld methods as manufactured by an approved manufacturer for the type of [pipe] [tank]. Electric arc welded connections and other types of welded connections to ferrous pipe and structures shall be approved before use.

3.4.3 Pipe Joints

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

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

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

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

3.4.3.2 Electrical Isolation of Structures

Perform electrical isolation of structures as follows:

a. Isolating Fittings: Isolating flanges and couplings shall be installed aboveground, or within manholes, wherever possible, but an isolating device that electrically separates a pipeline shall not be installed in a confined area where a combustible atmosphere may collect unless precautions are taken to prevent arcing such as by means of externally located surge arresters, grounding cells, or other means. Isolating flanges and couplings in lines entering buildings shall be located at least 300 mm 12 inch above grade or floor level. Pipelines entering buildings either below or above ground shall be electrically isolated from the structure wall with an electrically isolating [gas tight wall sleeve.] [wall sleeve.]

b. Gas Distribution Piping: Electrical isolation shall be provided at each building riser pipe to 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.

c. [Steam] [High Temperature] [Chilled] [Water] [Line Supply and Return Piping] [Line Conduit]: Electrical isolation shall be provided at each building entrance, and at other locations as indicated.

d. [Fuel] [Gasoline] [Storage Tanks] [Fire Suppression] [_____]: Electrical isolation shall be provided in each pipe [at the building] [at the tank] as shown.

e. Copper Piping: Copper piping shall be [electrically isolated at both ends of the pipe run] [wrapped with pipeline tape and electrically isolated at both ends].

f. Underground Storage Tanks (UST): Tanks shall be electrically isolated from other metallic structures. Components protected with the tank such as pipes, vents, anchors, and fill pipes shall be bonded to the tank.

3.4.4 Dissimilar Metals

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NOTE: This paragraph will be coordinated with and referenced in mechanical and electrical specifications.
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Buried piping of dissimilar metals including new and old steel piping, excepting valves, shall be electrically separated by means of electrically insulating joints at every place of connection. The insulating joint, including the pipes, shall be coated with an underground type dielectric coating for a minimum distance of 10 diameters on each side of the joint.

3.4.5 Ferrous Valves

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

3.4.6 Brass or Bronze Valves

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

3.4.7 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, shall be coated with an underground type dielectric coating for a minimum distance of 3 diameters on each side of the junction.

3.4.8 Casing

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NOTE: This paragraph will be deleted if mechanical and electrical specifications include these requirements.
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Where a pipeline is installed in a casing under a roadway or railway, the pipeline shall be electrically isolated from the casing, and the annular space sealed against incursion of water.

3.4.9 Test Stations

Test stations shall be of the type and location shown and shall be [curb box] [post] mounted. Buried electrically isolating joints shall be provided with test wire connections brought to a test station. Changes in designated location shall have prior approval. Unless otherwise shown, other test stations shall be located 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 ends of an insulating joint are not accessible above ground for testing purposes.

3.5 TRAINING COURSE

Conduct a training course for the operating staff as designated by the Contracting Officer. The training period shall consist of a total of [16] [_____] hours of normal working time and shall start after the system is functionally completed but prior to final acceptance tests. Submit the proposed Training Course Curriculum (including topics and dates of discussion) indicating that all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations, including testing procedures included in the maintenance instructions, are to be covered. The field instructions shall cover all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations, including testing procedures included in the maintenance instructions. At least 14 days prior to date of proposed conduction of the training course, submit the training course curriculum for approval, along with the proposed training date. Training shall consist of demonstration of test equipment, providing forms for test data and the tolerances which indicate that the system works satisfactorily.

3.6 TESTS AND MEASUREMENTS

Submit test reports in booklet form tabulating field tests and measurements performed, upon completion and testing of the installed system and including close interval potential survey, casing and interference tests, final system test verifying protection, insulated joint and bond tests, and holiday coating test. Submit a certified test report showing that the connecting method has passed a 120-day laboratory test without failure at the place of connection, wherein the anode is subjected to maximum recommended current output while immersed in a 3 percent sodium chloride solution. Each test report shall indicate the final position of controls.

3.6.1 Baseline Potentials

Each test and measurement will be witnessed by the Contracting Officer. Notify the Contracting Officer a minimum of 5 working days prior to each test. After backfill of the [pipe] [tank] [_____] and anodes is completed, but before the anodes are connected to the [pipe] [tank] [_____], the static potential-to-soil of the [pipe] [tank] [_____] shall be measured.

The locations of these measurements shall be identical to the locations specified for [pipe-] [tank-] [_____] to-reference electrode potential measurements.

3.6.2 Isolation Testing

Before the anode system is connected to the [pipe] [tank] [_____], an isolation test shall be made at each isolating joint or fitting. This test shall 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 shall be reported to the Contracting Officer.

3.6.2.1 Insulation Checker

Use a Model 601 insulation checker, as manufactured by ["Gas Electronics"] [_____] [or] [an approved equal], for isolating joint (flange) electrical testing in accordance with manufacturer's operating instructions. 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 at near zero on the meter scale. Location of the fault shall be determined from the instructions and the joint shall be repaired. If an isolating joint is located inside a vault, the pipe shall be sleeved with insulator when entering and leaving the vault.

3.6.2.2 Cathodic Protection Meter

Use a Model B3A2 cathodic protection meter, as manufactured by ["M. C. Miller"] [_____] [or] [an approved equal] using the continuity check circuit for isolating joint (flange) electrical testing. Perform this test in addition to the Model 601 insulation checker. Continuity is checked across the isolated joint after the test lead wire is shorted together and the meter adjusted to scale. A full scale deflection indicates the system is shorted at some location. The Model 601 verifies that the particular insulation under test is good and the Model B3A2 verifies that the system is isolated. If the system is shorted, further testing shall be performed to isolate the location of the short.

3.6.3 Anode Output

After the rectifier is energized, the current output of the individual anode leads shall be measured by using an approved method. This may be done with a shunt and MV meter, a low-resistance ammeter, or a clamp-on milliammeter. The total current shall be measured and compared to the sum of all anode currents and to the rectifier output current. If an individual anode output current meets or exceeds the recommended output for that anode, the system shall be turned down or balancing resistors installed. Calculation of the wattage of the resistors shall be sufficient to handle the maximum load which will be encountered on the anode lead. All measurements obtained, the date, time, and locations of all measurements shall be recorded.

3.6.4 Electrode Potential Measurements

Upon completion of the installation and with the entire cathodic protection system in operation, electrode potential measurements shall be made using a copper-copper sulphate 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 shall be identical to the locations used for baseline potentials. The values obtained and the date, time, and locations of measurements shall be recorded. No less than 8 measurements shall be made over any length of line or component. Additional measurements shall be made at each distribution service riser, with the reference electrode placed directly over the service line.

3.6.5 Location of Measurements

3.6.5.1 Coated Piping or Conduit

For coated piping or conduit, take measurements from the reference electrode located in contact with the earth, directly over the pipe. Connection to the pipe shall be made at service risers, valves, test leads, or by other means suitable for test purposes. Pipe to soil potential measurements shall be made at intervals not exceeding [0.75] [1.5] [122] [_____] m [2.5] [5] [400] [_____] feet. The Contractor may use a continuous pipe to soil potential profile in lieu of 0.75 m 2.5 ft interval pipe to soil potential measurements. Additional measurements shall be made at each distribution service riser, with the reference electrode placed directly over the service line adjacent to the riser. Potentials shall be plotted versus distance to an approved scale. Locations where potentials do not meet or exceed the criteria shall be identified and reported to the Contracting Officer.

3.6.5.2 Underground Tanks

For underground tanks, make a minimum of three measurements taken from the reference electrode located:

a. Directly over the center of the tank.

b. At a point directly over the tank and midway between each pair of anodes.

c. At each end of the tank.

3.6.6 Casing Tests

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

3.6.7 Interference Testing

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NOTE: Adverse effects may be caused by the foreign pipeline.

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Before final acceptance of the installation, interference tests shall 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 shall be made.

3.6.8 Holiday Test

Repair any damage to the protective covering, during transit and handling, before installation. After field coating and wrapping has been applied, inspect the entire pipe by an electric holiday detector with impressed current in accordance with NACE SP0188 using a full ring, spring type coil electrode. The holiday detector shall be equipped with a bell, buzzer, or other type of audible signal which sounds when a holiday is detected. Holidays in the protective covering shall be repaired upon detection. Occasional checks of holiday detector potential will be made by the Contracting Officer to determine suitability of the detector. Furnish labor, materials, and equipment necessary for conducting the inspection. Inspect the coating system for holes, voids, cracks, and other damage during installation.

3.6.9 Recording Measurements

Record all [pipe-] [tank-] to-soil potential measurements including initial potentials where required. Locate, correct and report to Contracting Officer any short circuits to foreign [pipes] [tanks] [_____] encountered during checkout of the installed cathodic protection system. [Pipe-] [Tank-] [_____] to-soil potential measurements are required on as many [pipes] [tanks] [_____] as necessary to determine the extent of protection or to locate short-circuits.

-- End of Section --