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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA-13112 (April 2005)
NASA
Superseding NASA-13112 (November 1004)

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SECTION 13112

CATHODIC PROTECTION SYSTEM (IMPRESSED CURRENT)

05/05

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SECTION 13112

CATHODIC PROTECTION SYSTEM (IMPRESSED CURRENT)
05/05

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NOTE: Delete, revise, or add to the text in this section to cover project requirements. Notes are for designer information and will not appear in the final project specification.

This guide specification covers the requirements for a cathodic protection system using impressed current anodes.

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PART 1 GENERAL

1.1 REFERENCES

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NOTE: The following references should not be manually edited except to add new references. References not used in the text will automatically be deleted from this section of the project specification.

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The publications listed below form a part of this section to the extent referenced:

ASME INTERNATIONAL (ASME)

ASME B16.39	(1998) Malleable Iron Threaded Pipe Unions Classes 150, 250, and 300

ASTM INTERNATIONAL (ASTM)

ASTM A 53/A 53M	(2002) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
ASTM D 1248	(1984; R 1989) Standard Specification for Polyethylene Plastics Molding and Extrusion Materials

NACE INTERNATIONAL (NACE)

NACE RP0169	(2002) Control of External Corrosion on Underground or Submerged Metallic Piping Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA TC 2	(2003) Electrical Plastic Tubing (EPT) and Conduit (EPC-40 and EPC-80)
NEMA WC 5	(1992; R 1993) Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2005) National Electrical Code 2005 Edition

U.S. DEPARTMENT OF DEFENSE (DOD)

MS MIL-I-1361	(1991c) Instrument Auxiliaries, Electrical Measuring; Shunts, Resistors, and Transformers

UNDERWRITERS LABORATORIES (UL)

UL 467	(2001) UL Standard for Safety Grounding and Bonding Equipment
UL 506	(2004) Standard for Specialty Transformers
UL 510	(1998) Insulating Tape
UL 514A	(2004) UL Standard for Safety - Metallic Outlet Boxes
UL 6	(2003) UL Standard for Safety for Electrical Rigid Metal Conduit-Steel

1.2 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01330, "Submittal Procedures," and edit the following list to reflect only the submittals required for the project. Submittals should be kept to the minimum required for adequate quality control. Include a columnar list of appropriate products and tests beneath each submittal description.

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The following shall be submitted in accordance with Section 01330, "Submittal Procedures," in sufficient detail to show full compliance with the specification:

SD-02 Shop Drawings

Installation Drawings shall be submitted in accordance with paragraph entitled, "Shop Drawings," of this section.

SD-03 Product Data

Manufacturer's catalog data shall be submitted for the following items. Spare parts data shall be furnished for each different item of materials and equipment specified. Data shall include a complete list of parts, special tools, and supplies with current unit prices and source of supply.

Impressed Current Anodes
Rectifiers
Coke Breeze
Miscellaneous Materials
Electrically Conductive Couplings
Cradles and Seals
Test Stations
Pavement Inserts
Insulating Pipe Sleeves

SD-06 Test Reports

Test reports shall be submitted in booklet form tabulating the following field tests and measurements performed in accordance with the paragraph entitled, "Tests and Measurements," of this section. Each test report shall indicate the final positions of controls.

Static Potential-To-Soil
Insulation Tests
Output Measurements
Electrode Potential Measurements
Casing Tests
Interference Tests

SD-07 Certificates

Evidence of qualifications of a Qualified Corrosion Engineer shall be submitted in accordance with the paragraph entitled, "Services of Corrosion Engineer," of this section.

SD-10 Operation and Maintenance Data

Contractor shall furnish Operating Instructions in accordance with paragraph entitled, "Rules," of this section.

1.3 GENERAL REQUIREMENTS

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NOTE: If Section 16003, "General Electrical Provisions," is not included in the project specification, applicable requirements therefrom should be inserted and the following paragraph deleted.
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Section 16003, "General Electrical Provisions," applies to work specified in this section.

1.3.1 Services of Corrosion Engineer

Contractor shall obtain the services of a corrosion engineer to supervise

and inspect the installation of the cathodic protection system. Qualified Corrosion Engineer refers to a person, who, by reason of his 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 on buried or submerged metallic piping systems and metallic tanks. Such person may be a licensed professional engineer or may be a person certified by the National Association of Corrosion Engineers if such licensing or certification includes suitable experience in corrosion control on buried or submerged metallic piping systems and metallic tanks. Corrosion engineer's name and qualifications shall be certified in writing to the Contracting Officer for approval prior to the start of construction.

Corrosion engineer shall ensure that the cathodic protection system is installed, tested, and placed into service in accordance with the requirements specified.

1.3.2 Rules

Installation shall conform to the requirements of NFPA 70.

Contractor shall furnish to the Contracting Officer [six] [_____] complete copies of operating instructions outlining the step-by-step procedures required for system start-up, operation and shutdown. Instructions shall include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment and their basic operating features.

Contractor shall furnish to the Contracting Officer [six] [_____] complete copies of maintenance instructions listing routine maintenance procedures, possible breakdowns and repairs, and troubleshooting guides. Operating instructions shall include diagrams for the system as installed, instructions in making [pipe-] [tank-] to-reference electrode measurements and frequency of monitoring.

1.4 DELIVERY, STORAGE, AND HANDLING

Storage area for anodes will be designated by the Contracting Officer. If anodes are not stored in a building, tarps or similar protection shall be used to protect anodes from inclement weather.

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)

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NOTE: The two grades shown represent manufacturing transition in practice. No significant difference in performance is involved. Either grade may be substituted for the other.

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	Percent by Weight	
Element	Grade 1	Grade 2
Silicon	14.20-14.75	14.20-14.75
Manganese	1.50 Max.	1.50 Max.
Carbon	0.70-1.10	0.75-1.15
Chromium	---------	3.25-5.00
Iron	Balance	Balance

2.1.1.2 Electrical Resistivity

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

2.1.1.3 Physical Properties (Nominal)

Tensile strength	15,000 psi 100,00 kilopascal
Compressive strength	100,000 psi 700,000 kilopascal
Brinell hardness	520
Density	7.0 grams per cubic centimeter
Melting point	2300 degrees F 1260 degrees C
Coefficient of expansion from 32 0 to 212 degrees F 100 degrees C	0.00000733 centimeter per degree F 0.000132 millimeter per degree C

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 or metallurgical coke breeze and the canisters shall be capped with tight fitting end caps secured to the body of the canister. Canister size shall be such that there is a minimum annular space of three inches 75 millimeter all around the anode. 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. 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 well ground bed, each anode located in the well shall be accompanied by a reel of continuous cable having the length indicated. No spliced connections shall be permitted in deep well cables.

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, and lightning arresters for both input and output, all wired and assembled in a weatherproof metal cabinet. 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 112 degrees F 44 degrees C 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 in such manner as 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

Voltmeters and ammeters shall be accurate to within plus or minus 2 percent of full scale at 80 degrees F 27 degrees C, and shall possess temperature stability above and below 80 degrees F 27 degrees C of at least 1 percent per 10 degrees F 6 degrees C. Separate meters shall be 2-1/2 inch 65 millimeter nominal size or larger.

2.2.1.4 Circuit Breaker

A single-pole, flush-mounted, fully magnetic, properly rated type circuit breaker shall be installed in the primary circuit of the rectifier supply transformer. Circuit breakers shall conform to the requirements of Section 16286, "Overcurrent Protective Devices."

2.2.1.5 Fuses

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

requirements of Section 16286, "Overcurrent Protective Devices."

2.2.2 Cabinet

Cabinet shall be constructed of not lighter than No. 16-gage 1.6 millimeter steel, and shall be provided with a full door. Door shall be hinged and have a hasp that will permit the use of a padlock. 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 comply with NFPA 70 and UL 467 including a grounding terminal in the cabinet. Grounding conductor from the terminal to the earth grounding system shall be solid or stranded copper not smaller than No. 6 AWG 4.12 millimeter diameter (No. 6 AWG). Earth grounding system shall consist of one or more 5/8-inch 16 millimeter diameter copper-clad steel rods. Ground rods shall be 8 feet 2400 millimeter long minimum.

2.2.2.3 Cabinet Paint System

Cabinet and supporting mounting shall be painted with the manufacturer's standard paint 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 hub type with gasketed covers. Conduit shall be securely fastened at 8-foot 2400 millimeter intervals or less. Splices shall be made in outlet fittings only. Conductors shall be color coded for identification.

2.2.4 Oil Immersed Enclosures

Enclosures shall be of 11-gage 3.1 millimeter steel or heavier, with an accessible drain plug. Oil level shall be clearly marked. 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. Gasket shall return to its original shape upon release of lid pressure. Gasket shall be attached to the tank or lid, and joints shall be free of gaps. Base mounting using 4-inch 100 millimeter high channels shall be provided.

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

1.0 to 2.0 ohm-centimeter - tightly compacted
10 to 15 ohm-centimeter - loosely compacted

2.3.1.2 Bulk Density

48 to 74 pounds per cubic foot. 770 to 1180 kilogram per cubic meter.

2.3.2 Metallurgical Coke Breeze (Processed)

Breeze shall conform to the following requirements:

2.3.2.1 Electrical Resistivity (Nominal)

10 ohm-centimeter - Max., tightly compacted
10 to 15 ohm-centimeter - lightly compacted
15 to 20 ohm-centimeter - loose

2.3.2.2 Bulk Density

38 to 42 pounds per cubic foot. 610 to 670 kilogram per cubic meter.

2.4 MISCELLANEOUS MATERIALS

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.
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Anode connecting wire shall be AWG No. [8] [_____] [3.25] [_____] millimeter diameter (No. [8] [_____] AWG) stranded copper wire with type CP high molecular weight polyethylene insulation, 7/64-inch 2.8 millimeter thick, 600 volt rating, in accordance with NEMA WC 5. Cable-to-anode contact resistance shall be 0.003 ohms maximum.

2.4.1.2 Anode Header Cable

Cable for anode header and distribution shall be AWG No. [8] [_____] [_____] millimeter diameter (No. [_____] AWG) stranded copper wire with type CP high molecular weight polyethylene, 7/64-inch 2.8 millimeter thick insulation, 600-volt rating, in accordance with NEMA WC 5.

2.4.1.3 Test Wires

Test wires shall be AWG No. 12 2.03 millimeter diameter (AWG No. 12) 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 1.27 or 0.635 millimeter diameter (AWG No. 16 or No. 22) nickel-chromium wire.

2.4.2 Anode Well Casing

Casing shall be [_____] inch millimeter outside diameter, 1/8-inch 3 millimeter minimum wall thickness black steel pipe, conforming to ASTM A 53/A 53M, Type E or S, Grade B.

2.4.3 Anode Centering Device for Deep Well Ground Beds

Anode centering device shall be capable of maintaining centering in the hole until coke breeze is packed in place.

2.4.4 Conduit

Rigid galvanized steel conduit and accessories shall conform to UL 6. Nonmetallic conduit shall conform to NEMA TC 2.

2.4.5 Test Boxes and Junctions Boxes

Boxes shall be outdoor type conforming to UL 514A.

2.4.6 Polyethylene Insulation

Polyethylene insulation shall comply with the requirements of ASTM D 1248 and of the following types, classes, and grades:

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

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

2.4.7 Calibrated Shunts

Shunts shall conform to MS MIL-I-1361.

2.4.8 Joint, Patch, Seal, and Repair Coating

2.4.8.1 Sealing and Dielectric Compound

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

2.4.8.2 Coating Compound

Coating compound shall be [cold-applied coal-tar base mastic] [hot-applied coal-tar enamel] [an approved pipeline wrapping].

2.4.8.3 Preformed Sheaths

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

2.4.8.4 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.

2.4.8.5 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.

2.4.8.6 Electrical Tape

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

2.5 Electrically Insulating Pipe Joints

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NOTE: Cathodic protection system will fail unless full consideration is given to specifications for electrically insulating pipe joints, electrically conductive pipe joints, and casing cradles and seals. If mechanical and electrical specifications do not adequately detail these products and/or do not accompany the contract documents, include paragraphs "Electrically Insulating Pipe Joints" and "Electrically Conductive Couplings."

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

2.5.1 Dielectric Unions

Dielectric unions shall conform to the requirements of ASME B16.39. Class designation for dimensional, strength and pressure requirements shall conform to the specified requirements for the piping system in which the union is to be installed. Insulating barrier shall limit galvanic current to one percent of the short circuit current in a corresponding metallic joint.

2.5.2 Flange Insulating Kits

Class designation for dimensional, strength, and pressure requirements shall conform to the specified requirements for the piping system in which the flange insulation set is to be installed.

Flanges in pipelines shall be electrically insulated by inserting an insulating gasket between the two flange faces. Insulating gaskets may have the same outside diameter as the flange, may fit within the bolt

circle of the flange faces, or may fit into the ring groove of ring type joint flanges. Flange coupling securing bolts shall be insulated from the flange face bolt holes by installing insulating sleeves over the shanks of the bolts and insulating washers and steel washers under the bolt heads and nuts. Insulating bolt sleeves shall be of sufficient length to extend half way inside the steel washer. Insulating sleeves and washers may be combined as a one piece unit.

2.5.2.1 Gasket Materials

Gaskets shall be manufactured from material having low water absorption and high compressive strength. Preference shall be given to materials with low "m" and "y" factors. The "y" factor is a measure of the compressive load required to establish an initial seal, while the "m" factor is an indication of the additional load required to hold fluid pressure needed to keep the seal in operation. The smaller these factors are, the less bolt loading is required.

2.5.2.2 Insulating Bolt Sleeve and Washer Materials

Insulating bolt sleeves and washers shall be manufactured from material having low water absorption, high dielectric strength, and low cold flow characteristics. They should be suitable for the service conditions of the particular application.

2.6 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.

2.7 CRADLES AND SEALS

Cradles and seals shall be of a type that is in regular factory production made for the purpose of electrically insulating the carrier pipe from the casing and preventing the incursion of water into the annular space.

2.8 TEST STATIONS

Stations shall be flush mounted type and shall be made of high impact molded glass filled polycarbonate with water tight conduit connections and lockable cover [with a cast-in legend, "C.P. Test"].

Stations shall be watertight so that electrical terminals are maintained in a dry environment when cabinet is submerged under water.

Stations shall be furnished with a [five] [_____] lead terminal board with terminals accessible from both sides. Terminal board shall be designed for easy removal from the housing to permit "above the surface of the ground" access for taking test readings.

Stations shall have color-coded covers for identification of the following underground piping systems.

PIPING SYSTEM	COLOR CODED COVER
Natural Gas	Yellow
Potable Water	White
Cooling Tower Water	Brown
Service Air	Black

PIPING SYSTEM	COLOR CODED COVER
Combustion Air	Gray

Stations shall be maintenance free and all hardware such as machine screws, washers, and hex nuts shall be [brass] [stainless steel].

Stations shall be designed and constructed for dimensional and electrical stability from minus 60 degrees F to plus 250 degrees F 50 degrees C to plus 120 degrees C.

2.9 PAVEMENT INSERTS

Pavements inserts shall be used to permit access to soil under paced areas for taking future pipe-to-soil potential readings over existing underground piping systems.

Pavement inserts shall be of the same construction and design as the test stations and shall be designed to be embedded in streets or sidewalks in urban and/or high vehicular traffic areas.

Pavement inserts shall be designed for flush mounting in paved areas.

Pavement inserts shall have color-coded covers to match color coding for test stations for identification of the underground piping systems.

Pavement inserts shall be maintenance free and hardware shall be brass or stainless steel.

2.10 INSULATING PIPE SLEEVES

Insulating pipe sleeves shall be provided between metallic piping and metal buildings, hangers, supports and other metal structures. Insulating sleeve shall completely surround the metallic pipe for the full length of the steel contact and shall effectively prevent contact between the cathodically protected metallic pipe and other metallic structures. Insulation material shall be micarta, plastic, PVC, or other suitable insulating material.

Insulating supports must prevent damage to the pipeline coating and accommodate relative movement, vibrations and temperature differentials.

PART 3 EXECUTION

3.1 CRITERIA OF PROTECTION

Criteria for determining the adequacy of protection on a buried [pipe] [tank] shall be in accordance with NACE RP0169 and shall be selected by the corrosion engineer as applicable.

3.1.1 Iron and Steel

One of the following methods shall apply:

a. A negative voltage of at least minus 0.85 volts as measured between the [pipe] [tank] and a saturated copper-copper sulphate reference electrode contacting the earth directly over the [pipe] [tank]. Determination of this voltage shall be made with the cathodic protection system in operation.

b. A negative voltage shift of at least 300 millivolts as measured between the [pipe] [tank] and a saturated copper-copper sulphate reference electrode contacting the earth directly over the [pipe] [tank]. Determination of this voltage shift shall be made with the protective current applied. These criteria apply to [pipes] [tanks] not in electrical contact with dissimilar metals.

c. 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. Voltage reading, after the immediate shift, shall be used as the base reading from which to measure polarization decay.

3.1.2 Aluminum

Aluminum [pipes] [tanks] shall under no circumstances be protected to a potential more negative than minus 1.20 volts, measured between the [pipe] [tank] and a saturated copper-copper sulphate reference electrode contacting the earth, directly over the [pipe] [tank]. 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 1.20 volts. Voltage shift criterion shall be one of the following:

a. A minimum negative voltage shift of 150 millivolts produced by the application of protective current. Voltage shift shall be measured between the [pipe] [tank] and a saturated copper-copper sulphate reference electrode contacting the earth directly over the [pipe] [tank].

b. A minimum negative polarization voltage shift of 100 millivolts measured between the [pipe] [tank] and a saturated copper-copper sulphate reference electrode contacting the earth, directly over the [pipe] [tank]. 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 percent] [50 percent] [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 4 inches. 100 millimeter. 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. Holes in the ground shall be sufficiently large to provide an annular space around the anode not less than 4 inches 100 millimeter. Anodes shall be centered in the hole and backfilled with calcined petroleum coke breeze or metallurgical coke breeze. Backfill shall be compacted.

In the event a rock strata is encountered prior to achieving specified augured hole depth, the Contractor shall notify the Contracting Officer. With the Contracting Officer's approval, the Contractor may then install the anodes horizontally to a depth at least as deep as the bottom of the pipe to be protected.

Anodes shall be installed a minimum of 3 feet 900 millimeter and a maximum of 10 feet 3000 millimeter from the line to be protected.

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. Holes in the ground shall be sufficiently larger in diameter than the canisters to facilitate easy lowering into the hole and backfilling. Space between the canister and the wall of the hole shall be completely backfilled with a wet slurry of earth free of stones.

In the event a rock strata is encountered prior to achieving specified augured hole depth, the Contractor shall notify the Contracting Officer. With the Contracting Officer's approval, the Contractor may then install the anodes horizontally to a depth at least as deep as the bottom of the pipe to be protected.

Anodes shall be installed a minimum of 3 feet 900 millimeter and a maximum of 10 feet 3000 millimeter from the line to be protected.

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 30 inches 800 millimeter 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. 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. Anodes shall be at the pipeline at depths, spacing, and locations shown. Anodes shall be buried [horizontally] [vertically].

3.2.2 Deep Well Ground Beds

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NOTE: For wells 300 feet 90 meter deep and deeper the use of a steel pipe tubing installed to the full depth of the well is usually preferred. Anodes, cable, and centering devices are strapped to the tubing as it is lowered into the hole. Tubing may be supported from the bottom of the well or hung from the casing head. Support tubing is also used to inject coke breeze slurry, back-filling the well from the bottom upward. If a support tubing is not used, it may be necessary to bail the well clear of water so that dry coke breeze can be placed and used to support anodes and cable as the installation proceeds upward. Slack in the installed cable near the anode connection is essential. A larger diameter hole than otherwise needed will facilitate tamping of backfill.

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Deep well ground beds shall consist of an installation of anodes supported in a well spaced one above the other and supported in place by a method that does not suspend the anodes from the connecting cable.

3.2.2.1 Anode Centering

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

3.2.2.2 Well Casing

Well casing shall be bare steel to a depth and elevation shown.

3.2.2.3 Casing Insulation

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 in the well 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, slack in the cable near each anode shall be provided and the cable

insulation shall be increased in thickness from 7/64 to 5/32 inch 2.8 to 4.0 millimeter utilizing an approved composite of plastic and elastomeric materials.

3.2.2.8 Backfill

Well shall be backfilled with calcined petroleum coke breeze or metallurgical coke breeze surrounding the anodes by a method that does not leave voids or bridging. 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. Number of days allowed for settling of the coke breeze shall be determined by the Contracting Officer. If the top level of coke breeze is below the level shown after settlement, additional coke breeze shall be put in the well. Anode and cable assemblies shall not be used for tamping backfill around another, previously placed anode unless recommended in writing by the manufacturer of the anode and cable assembly.

Top portion of the well above the level of the coke breeze shall be filled with washed gravel.

Top of the well shall be vented to atmosphere.

3.3 MISCELLANEOUS INSTALLATION

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NOTE: Cathodic protection system will fail unless full engineering considerations are applied to selection, location and installation of electrically conductive joints and electrically insulating 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 an accredited corrosion specialist. 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.

Type of electrical insulating pipe joint to be used requires engineering design consideration. In general, the dielectric parts of an insulating 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 insulating 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. Requirement for insulating 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 insulating 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 insulation fitting should be used.

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3.3.1 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 4 by 4-inch 100 by 100 millimeter cross-arm.]

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NOTE: A single split bolt will work loose when the wires it connects are moved. A minimum of two split bolts will prevent this from happening. 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. 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.

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3.3.2 Anode Lead Connections

If the anode lead wire is not of sufficient length to connect the anode to the pipe or test station, an additional length of AWG No. 8 3.25 millimeter diameter stranded copper wire shall be added and spliced to the anode lead wire using [a homogeneous exothermic welding process] [or] [a minimum of

two split bolts of suitable size]. Splice shall be insulated with two half-lapped layers of 3/4-inch 20 millimeter wide rubber tape and two half-lapped layers of 3/4-inch 20 millimeter wide polyethylene tape.

Connections of anode lead wire to pipe shall be made by an approved exothermic welding process following the instructions of the manufacturer. Installation shall be in strict accordance to manufacturer's recommendations.

Before the anode lead connection is made, the pipe shall be inspected to verify that the condition of the pipe is sound for making an exothermic weld. If the condition of the pipe is proven to be sound, the pipe connection area shall be cleaned to bare metal by means of scraping, filing or other approved methods. Cleaning of the pipe shall be by manual methods and no power-driven wheels or wire brushes shall be used.

Before the anode lead connection is made to a natural gas pipeline, an approved gas leak detector shall be used to determine if there is any gas leakage near the pipe area to be welded. Should a gas leak be discovered, it shall be brought to the immediate attention of the Contracting Officer. Connection shall not be made until the leak is properly repaired and an alternative safe location for the connection is approved by the Contracting Officer and the Contractor's corrosion specialist.

After the anode lead or test lead to pipe connections have been made, they shall be covered with mastic sealant and plastic shield.

Anode lead connection to test station terminals shall be made with insulated compression ring terminals.

3.3.3 Pipe Joints

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NOTE: This paragraph will be deleted if mechanical and electrical specifications include the requirements given.

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3.3.3.1 Electrical Continuity

Underground pipe shall be electrically continuous except at places where electrically insulating 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. Bonding connections shall be made by the exothermic welding process.

b. Mechanical joints designed to provide electrical continuity shall meet manufacturer's published standards.

3.3.3.2 Coating

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, all 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 following recommendations of the coupling or fitting manufacturer.

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 [polyurethane foam having a cellular structure that will not absorb water] [cold-applied dielectric compound] [hot applied bituminous compound not exceeding 275 degrees F 135 degrees C in application temperature].

3.3.3.3 Electrical Isolation of Structures

Electrical isolation of structures shall be as follows:

a. Insulating Fittings: Insulating flanges and couplings shall be installed above ground, or within manholes, wherever possible, but an insulating 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 lightning arresters, grounding cells, or other means. Insulating flanges and couplings in lines entering buildings shall be located at least 12 inches 300 millimeter 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.

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: 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].

3.3.4 Dissimilar Metals

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NOTE: This paragraph will be deleted if mechanical and electrical specifications include the requirements given.
****

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. 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.

3.3.5 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.

3.3.6 Brass or Bronze Valves

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

3.3.7 Metal Pipe Junction

If the dissimilar metal pipe junction, including valves, is not buried and 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.

3.3.8 Casing

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NOTE: This paragraph will be deleted if mechanical and electrical specifications include the requirements given.

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

3.3.9 Test Stations

Test stations shall be of the type and installed at the location shown and shall be [curb box mounted] [post mounted] [indoor mounted] [flush mounted in concrete]. Buried electrically insulating joints shall be provided with test wire connections brought to a test station. Unless otherwise shown, other test stations shall be located as follows:

a. At 1,000-foot 300 meter 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 insulating joint are not accessible above ground for testing purposes.

Test stations shall be installed with color-coded covers to identify the piping system on which it is installed as specified in this specification. Each new test station shall be identified by number as depicted on the drawings. Contractor shall furnish and install a screw mounted 2-inch 50 millimeter round brass identifying tag with 1/2-inch 15 millimeter stamped characters onto each test station cover.

Location of the pipeline in relation to the test station shall be indicated by an arrow inscribed in the concrete base of the test station.

3.3.10 Pavement Inserts

Pavement inserts shall be flush mounted and installed in paved areas as shown on the drawings. Inserts shall be installed with color-coded covers to identify the piping system on which it is installed as specified in this specification.

Pavement inserts shall be installed as closely as possible over the center line of underground pipeline to permit accurate evaluation of future pipe-to-soil potential surveys. Contractor shall use and furnish all necessary labor and pipe location equipment to locate and mark center lines of underground piping systems. Use of reference dimensions on contract drawings shall not be used for determining the center lines of underground piping systems.

3.4 TESTS AND MEASUREMENTS

3.4.1 Baseline Potentials

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. Locations of these measurements shall be identical to the locations specified for [pipe-] [tank-] to-reference Electrode Potential Measurements. Initial measurements shall be recorded.

3.4.2 Insulation Tests

Before the anode system is connected to the [pipe] [tank], an insulation test shall be made at each insulating joint or fitting. This test shall demonstrate that no metallic contact, or short circuit exists between the two insulated sections of the [pipe] [tank]. Any insulating fittings installed and found to be defective shall be reported to the Contracting Officer.

3.4.3 Anode Output

As the anodes or groups of anodes are connected to the [pipe] [tank], current Output Measurements shall be taken with an approved low resistance ammeter. Values obtained and the date, time, and locations shall be recorded.

3.4.4 [Pipe-] [Tank-] to-Reference Electrode Potential Measurements

Upon completion of the installation and operation of the entire cathodic protection system 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 100,000 ohms per volt and a full scale of one or two volts. Locations of these measurements shall be identical to the locations used for baseline potentials. Values obtained and the dates, times, and locations of measurements shall be recorded.

3.4.5 Location of Measurements

3.4.5.1 Coated Piping or Conduit

For coated piping or conduit, measurements shall be taken from the reference electrode 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. Measurements shall be made at intervals not exceeding 400 feet 120 meter. In no case shall less than three measurements be made over any length of line. Additional measurements shall be made at each distribution service riser, with the reference electrode placed directly over the service line.

3.4.5.2 Underground Tanks

For underground tanks, measurements shall be 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.

In no case shall less than three measurements be made.

3.4.6 Casing Tests

Before final acceptance of the installation, the electrical separation of carrier pipe from casings shall be tested and any short circuits corrected at no expense to the government.

3.4.7 Interference Tests

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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.

3.4.8 Recording Measurements

All [pipe-] [tank-] to-soil potential measurements including initial potentials, where required shall be recorded. Contractor shall 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.

3.5 TRAINING COURSE

Contractor shall conduct a training course for the operating staff as designated by the Contracting Officer. Training period shall consist of a total of [_____] hours of normal working time and shall start after the system is functionally completed but prior to final acceptance tests. Field instructions shall cover all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations. Contracting Officer shall be notified at least 14 calendar days prior to date of proposed conduction of the training course.

3.6 SHOP DRAWINGS

Installation Drawings shall be submitted for cathodic protection systems consisting of a complete list of equipment and materials including manufacturer's descriptive and technical literature, catalog cuts, 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. Drawings shall also 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.

-- End of Section --