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NASA-13110 (June 2004)

NATIONAL AERONAUTICS **NASA**

AND SPACE ADMINISTRATION **Superseding NASA-13110**

(September 1999)

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SECTION 13110

CATHODIC PROTECTION
06/04

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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 utilizing continuous flow direct current from sacrificial anodes.

This specification is intended to be used in specifying a cathodic protection system to protect metal surfaces efficiently against corrosion by producing a continuous flow of direct current from sacrificial anodes to the metal to be protected. Anodes should be of sufficient size and quantity to protect the buried metal items for a specified number of years before replacement. U.S. Department of Transportation has issued regulations requiring the application of cathodic protection to natural gas pipelines, liquid natural gas pipelines, petroleum pipelines, petroleum products pipelines, liquid petroleum gas pipelines, and petroleum storage facilities. Title 49 of the Code of Federal Regulations, Parts 191, 192, 193, and 195 should be consulted for applicable cathodic protection requirements for specific applications.

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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 B 418	(2001) Cast and Wrought Galvanic Zinc Anodes

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)

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2002) National Electrical Code

UNDERWRITERS LABORATORIES (UL)

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-01 Preconstruction Submittals

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

SD-02 Shop Drawings

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

SD-03 Product Data

Manufacturer's catalog data shall be submitted for the following items:

Anodes
Electrical Wire
Electrical Connections
Conduit
Test Boxes and Junction Boxes
Coatings
Preformed Sheaths
Epoxy Potting Compound
Pavement Inserts
Insulating Pipe Sleeves
Electrically Insulating Pipe Joints
Electrically Conductive Couplings
Casing Centering Cradles and Casing Seals

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.

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

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.

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. Package anodes, damaged as a result of improper handling or exposure to rain, shall be resacked by the Contractor and the required backfill added.

PART 2 PRODUCTS

2.1 ANODES

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NOTE: Magnesium anodes have the following nominal properties:

Amp-hr/lbkg -- Theoretical ------ 1000 450
Current Efficiency ------------ 50 percent
Amp-hr/lbkg ------- Actual ------ 500 230
LbKg/Amp -yr - Consumption Rate - 17 7.7
Solution Potential - Volts to a Copper - Copper Sulfate Electrode in Gypsum Backfill:

Type 63 Alloy - Volts --------------------------- -1.55

Mg-Mn Alloy - Volts ---------------------------- -1.73

The following tables show typical sizes available:

TYPICAL MAGNESIUM ANODE SIZES

(Cross sections may be round, square, or D-shaped)

NOMINAL GROSS WT. NOMINAL WT.LBS.	APPROX. SIZE (IN.)	LBS. PACKAGED IN BACKFILL	PACKAGE DIMENSIONS (IN.)
3	3 X 3 X 5	8	5-1/4 X 5-1/4 X 8
5	3 X 3 X 5	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

TYPICAL MAGNESIUM ANODE SIZES

32	5 X 5 X 20-1/2	68	8-1/2 X 28
50	7 X 7 X 16	100	10 X 24

Extra Long Magnesium Anodized (a)

10(a)	1-1/2 x 1-1/2 x 70		
16(a)	2 x 2 x 60		
17	3-1/2 x 3-1/2 x 28	44	5-1/2 x 5-1/2 x 38
40(a)	3 x 3 x 60		
50	5 x 5 x 31	50	8-1/2 x 40
60(a)	4 x 4 x 60		

TYPICAL MAGNESIUM ANODE SIZES

(Cross sections may be round, square, or D-shaped)

NOMINAL WT.(KG)	APPROX. SIZE (MM)	NOMINAL GROSS WT. (KILOGRAM) IN BACKFILL	PACKAGE DIMENSIONS (MM)
1.4	75 X 75 X 125	3.6	133 X 133 X 200
2.3	75 X 75 X 125	5.9	133 X 133 X 280
4.1	75 X 75 X 360	12.2	133 X 500
5.4	100 X 100 X 300	14.5	191 X 450
7.7	100 X 100 X 430	20.4	191 X 600
14.5	125 X 125 X 520	30.8	216 X 700
22.7	180 X 180 X 400	45.4	250 X 600

Extra Long Magnesium Anodized (a)

4.5	38 X 38 X 1780		
7.3	50 X 50 X 1520		
7.7	89 X 89 X 700	20	140 X 140 X 950
18.1	75 X 75 X 1500		
22.7	125 X 125 X 775	22.7	216 X 1000
27.2	100 X 200 X 1500		

(a) Extra long anodes furnished bare - backfill applied around anodes in augured holes.

The four alloy compositions generally represent a range of prices from the lowest (Type I) to the highest (Mg-Mn). However, the lowest cost anode may not necessarily represent the lowest cost installation since fewer anodes having a higher driving potential may be required in some installations. Other criteria for aiding in selection are:

a. Type I

(1) Lowest cost available.
(2) Good efficiency at relatively high current

density.
(3) Best all around choice in salt and brackish waters and low resistivity soils.
(4) Less wasted current in low resistivity environments than Mg-Mn alloy because of lower potential.
(5) Available from five metal anode producers.
(6) Solution potential: -1.55 volts.

b. Type II

(1) Best all around choice for low to moderate resistivity soils.
(2) Suitable for hot-spot protection where the protection requirement is moderate.
(3) Long length anodes are suitable for installation in high resistivity soils.
(4) Available from five metal anode producers.
(5) Solution potential: -1.55 volts.

c. Type III

(1) For applications similar to Type II except slightly higher efficiency.
(2) More stringent control of impurities than in Types I and II tend to result in more consistent current output during service life.
(3) Available from five metal anode producers.
(4) Solution potential: -1.55 volts.

d. Mg-Mn Alloy

(1) Highest driving potential of any type.
(2) Best all around choice for high resistivity soils.
(3) Best for hot-spots that require higher current output than available from the Types I, II and III.
(4) Available from two metal anode producers.
(5) Solution potential: -1.73 volts.
****

2.1.1 Magnesium Anodes

Magnesium anodes shall be [Type I] [Type II] (D,E) [Type III] [magnesium-manganese] corresponding to the applicable chemical composition listed in the following table:

PERCENT BY WEIGHT

ELEMENT	TYPE I	TYPE II	TYPE III	MG-MN ALLOY
Aluminum	5.0 - 7.0	5.3 - 6.7	5.3 - 6.7	0.010 Max.
Zinc	2.0 - 4.0	2.5 - 3.5	2.5 - 3.5	
Manganese	0.15 Min.	0.15 Min.	0.15 Min.	0.50 - 1.30
Copper	0.1 Max.	0.05 Max.	0.02 Max.	0.02 Max.
Silicon	0.30 Max.	0.30 Max.	0.10 Max.	
Iron	0.003 Max.	0.003 Max.	0.003 Max.	0.03 Max.
Nickel	0.003 Max.	0.003 Max.	0.002 Max.	0.001 Max.
Others	0.30 Max.	0.30 Max.	0.30 Max.	0.05 each

PERCENT BY WEIGHT

ELEMENT	TYPE I	TYPE II	TYPE III	MG-MN ALLOY
				or 0.30 Max. Total
Magnesium	Balance	Balance	Balance	Balance

2.1.2 Zinc Anodes

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NOTE: Zinc anodes are practical for use in low resistivity soil on the order of 2500 ohm-cm or less due to the low available driving voltage, on the order of -0.25 volt. The following table shows typical sizes available:
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TYPICAL ZINC ANODE SIZES

NOMINAL BARE WEIGHT (LB.)	NOMINAL BARE ANODE DIMENSIONS (IN.)	GROSS WEIGHT PACKAGED IN BACKFILL
5	1.4 X 1.4 X 9	15
12	1.4 X 1.4 X 24	35
18	1.4 X 1.4 X 36	50
30	1.4 X 1.4 X 60	80
30	2 X 2 X 30	60
45	2 X 2 X 45	85
60	2 X 2 X 60	105

TYPICAL ZINC ANODE SIZES

NOMINAL BARE WEIGHT (KG)	NOMINAL BARE ANODE DIMENSIONS (MM)	GROSS WEIGHT PACKAGED IN BACKFILL
2.3	36 X 36 X 225	6.8
5.4	36 X 36 X 600	15.9
8.2	36 X 36 X 900	22.7
13.6	36 X 36 X 1500	36.6
13.6	50 X 50 X 750	27.2
20.4	50 X 50 X 1125	38.6
27.2	50 X 50 X 1500	47.6

Zinc anodes shall conform to the requirements of ASTM B 418, Type II.

2.1.3 Connecting Wire

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NOTE: Type RHH should be used under hot asphalt.
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Wire shall be AWG No. 12 2.03 millimeter diameter (AWG No. 12)solid copper wire, not less than 10 feet 3000 millimeter long, unspliced, complying with NFPA 70, Type [TW] [RHH] insulation. [Connecting wires for magnesium anodes shall be factory installed with the place of emergence from the anode in a cavity sealed flush with a dielectric sealing compound.] [Connecting wires for zinc anodes shall be factory installed with the place of connection to the protruding steel core completely sealed with a dielectric material.]

2.1.4 Artificial Backfill

Anodes shall be factory packaged with an artificial backfill in a water-permeable fabric sack or cardboard container. Anodes shall be packaged on a vibrating platform to attain dense packing. Centering shall be assured by means of spacers.

Artificial backfill shall have the following composition:

Material	Approximate Percent by Weight
Gypsum	75
Bentonite	20
Sodium Sulfate	5
Total	100

2.2 ELECTRICAL WIRE

Wire shall be AWG No. 8 [_____] 3.25 [_____] millimeter diameter (AWG No. 8 [_____] stranded copper wire with Type [TW] [RHW-USE] [RHW-USE] [_____] insulation conforming to NFPA 70.

2.3 ELECTRICAL CONNECTIONS

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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 the 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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Connecting wire splicing shall be performed by the use of copper compression connections or exothermic welds. [Split-bolt connections shall be used only if compression connections or exothermic welded connections are not possible. Where split-bolt connections are necessary, a minimum of two split bolts shall be used.]

2.4 CONDUIT

Rigid galvanized steel conduit and accessories shall conform to UL 6. Non-metallic conduit shall conform to NEMA TC 2.

2.5 TEST BOXES AND JUNCTION BOXES

Boxes shall be outdoor type conforming to UL 514A.

2.6 JOINT, PATCH, SEAL, AND REPAIR COATINGS

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 1/2-inch 15 millimeter thick.

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

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

2.7 PREFORMED SHEATHS

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

2.8 EPOXY POTTING COMPOUND

Compound for encapsulating electrical wire splices to be buried underground shall be a two-package system made for the purpose.

2.9 TEST STATIONS

Stations shall be flush mounted type and shall be made of high impact molded glass filled polycarbonate with watertight conduit connections and shall have 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
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 51 degrees C to plus 121 degrees C.

2.10 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 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.

2.11 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.

2.12 ELECTRICALLY INSULATING PIPE JOINTS

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] [non-flexible flanged type electrically insulating pipe joints to be field assembled] [non-flexible factory assembled electrically insulating pipe joints designed with stub ends for installation by welding and providing pull-out strength with a factor of safety].

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

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

2.12.1 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.

2.12.2 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.

2.12.2.1 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.

2.12.2.2 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.

2.13 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.

2.14 CASING CENTERING CRADLES AND CASING 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.

PART 3 EXECUTION

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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

underground pipe 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:

(1) Deflection stresses.
(2) Pull-out stresses.
(3) Expansion-contraction due to temperature changes.
(4) Is function as a union necessary?
(5) Is field assembly of critical parts practical?
(6) Hazardous locations to be avoided.
(7) Accessibility if above ground.
(8) Location of test box is below ground.
(9) Importance of coating the adjacent pipe if below ground.
(10) 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 existing 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. Since it is not usually practical to insulate brass or bronze valves in underground ferrous piping, such valves should not be used in ferrous piping and if already present should be replaced with ferrous valves.

If mechanical and electrical specifications do not include the requirements given below or do not accompany the contract documents, the applicable paragraphs given below will be included. In case of such inclusions, paragraphs "Criteria of Protection" and "Tests and Measurements" will become the last two paragraphs in PART 3 EXECUTION.
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3.1 INSTALLATION

All equipment shall be installed in accordance with the manufacturer's recommendations.

3.1.1 Anodes

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NOTE: It is rarely expedient to limit the driving voltage of single anodes or group anodes with resistors. Variation in driving voltage due to seasonal variations in environment may be greater than the adjustment provided by the resistor. If resistors are used, frequent monitoring of protection must be made to ensure that protection criteria are maintained.

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Anodes of the size indicated shall be installed at the locations shown. Locations may be changed to clear obstructions if approved. Anodes shall be installed as indicated in a dry condition after any plastic or waterproof protective covering has been completely removed from the water permeable, permanent container housing the anode metal. Anode connecting wire shall not be used for lowering the anode into the hole. Annular space around the anode shall be backfilled with fine earth in 6-inch 150 millimeter layers and each layer shall be hand tamped. Care must be exercised not to strike the anode or connecting wire with the tamper. Approximately 5 gallons 20 liter of water shall be applied to each filled hole after anode backfilling and tamping has been completed to a point about 6 inches 150 millimeter above the anode. After the water has been absorbed by the earth, backfilling shall be completed to the ground surface level.

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.

Single anodes spaced as shown shall be [direct connected] [connected through a test station] to the pipeline, allowing adequate slack in the connecting wire to compensate for movement during backfill operation.

Groups of anodes, in quantity and location shown, shall be connected to a collector cable. Collector cable shall only make contact with the structure to be protected through a test station.

Resistance wires shall not be used to reduce the current output of individual or group anodes.

Connections to [ferrous pipe] [metal tanks] shall be made by exothermic weld methods manufactured 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.

3.1.2 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 (AWG No. 8) 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.

3.1.3 Test Stations

Test stations shall be of the type shown 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.

3.1.4 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.

3.2 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.

3.2.1 Iron and Steel

One of the following methods shall apply:

3.2.1.1 850 MV Negative Voltage

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

3.2.1.2 300 MV Negative Voltage

A negative voltage shift of at least 300 millivolts as measured between the [pipe] [tank] and a saturated copper-copper sulfate 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.

3.2.1.3 100 MV Polarization Voltage

A minimum polarization voltage shift of 100 millivolts as measured between the [pipe] [tank] and a saturated copper-copper sulfate 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.

3.2.2 Aluminum

Aluminum [pipes] [tanks] shall not, under any circumstances, be protected to a potential more negative than minus 1.20 volts, measured between the [pipe] [tank] and a saturated copper-copper sulfate 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:

3.2.2.1 150 MV Negative Voltage

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 sulfate reference electrode contacting the earth directly over the [pipe] [tank].

3.2.2.2 100 MV Negative Voltage

A minimum negative polarization voltage shift of 100 millivolts measured between the [pipe] [tank] and a saturated copper-copper sulfate reference electrode contacting the earth, directly over the [pipe] [tank]. Polarization voltage shift shall be determined as outlined for iron and steel.

3.3 TESTS AND MEASUREMENTS

3.3.1 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.

3.3.2 Insulation Testing

Before the anode system is connected to the [pipe] [tank], Insulation Tests 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.

3.3.3 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 location shall be recorded.

3.3.4 [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 sulfate 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 1 or 2 volts. Locations of these measurements shall be identical to the locations used for the baseline potentials. Values obtained and the dates, times, and locations of measurements shall be recorded.

3.3.5 Location of Measurements

3.3.5.1 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.

3.3.5.2 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.

3.3.6 Casing Tests

Electrical separation of carrier pipe from casings shall be tested and any short circuits corrected.

3.3.7 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.

3.3.8 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.

3.4 PIPE JOINTS

3.4.1 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 electrical continuity requirements.

The following 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.

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

3.4.2 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.

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.

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].

3.5 ELECTRICAL ISOLATION OF STRUCTURES

3.5.1 Insulating Fittings

Insulating flanges and couplings shall be installed above ground, or within manholes, wherever possible. 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.

3.5.2 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.

3.5.3 Electrical Isolation

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

3.5.4 [Fuel,] [Gasoline,] [Storage,] and [_____] Tanks

Electrical isolation shall be provided in each pipe at the [building] [tank] as shown.

3.5.5 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].

3.6 DISSIMILAR METALS

3.6.1 Underground Dissimilar Piping

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 pipe, shall be coated with an underground type dielectric coating for a minimum distance of 10 diameters on each side of the joint.

3.6.2 Underground Dissimilar 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.

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

3.6.3 Above ground Dissimilar Pipe and Valves

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

3.7 CASING

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

3.8 SHOP DRAWINGS

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