****

USACE / NAVFAC / AFCEC / NASA **UFGS-26 42 19.00 20 (April 2006)**

Preparing Activity: NAVFAC **Replacing without change UFGS-13111N (August 2001)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2019

****

SECTION TABLE OF CONTENTS

DIVISION 26 - ELECTRICAL

SECTION 26 42 19.00 20

CATHODIC PROTECTION BY IMPRESSED CURRENT

04/06

-- End of Section Table of Contents --

****
USACE / NAVFAC / AFCEC / NASA **UFGS-26 42 19.00 20 (April 2006)**

Preparing Activity: NAVFAC **Replacing without change UFGS-13111N (August 2001)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2019
****

SECTION 26 42 19.00 20

CATHODIC PROTECTION BY IMPRESSED CURRENT
04/06

****
NOTE: This guide specification covers the requirements for underground piping and buried or submerged structure cathodic protection systems using impressed current systems.

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

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

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**
****

****
NOTE: The requirements for the cathodic protection systems should be determined by a corrosion engineer following the criteria, design, and installation recommendations included in the National Association of Corrosion Engineers (NACE) Standard SP0169, Control of External Corrosion on Underground or Submerged Metallic Piping Systems and others listed in the specification.
****

****
NOTE: The following information should be on the drawings:

1. Locations of the subject pipe or structure and all crossing and nearby underground pipes and structures.

2. Locations of all anodes, rectifiers, power sources and test stations.

3. Locations of all insulating flanges and unions.

4. Installation details of anodes, rectifiers and bond cables.

5. Locations of nearby cathodic protection systems.

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

7. Remote indicating or control requirements.
****

PART 1 GENERAL

1.1 REFERENCES

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

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

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASME INTERNATIONAL (ASME)

ASME B1.1	(2003; R 2018) Unified Inch Screw Threads (UN and UNR Thread Form)
ASME B1.20.1	(2013) Pipe Threads, General Purpose (Inch)
ASME B16.5	(2017) Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard
ASME B16.21	(2016) Nonmetallic Flat Gaskets for Pipe Flanges

ASME B16.25	(2017) Buttwelding Ends
ASME B16.39	(2014) Standard for Malleable Iron Threaded Pipe Unions; Classes 150, 250, and 300
ASME B18.2.1	(2012; Errata 2013) Square and Hex Bolts and Screws (Inch Series)
ASME B18.2.2	(2015) Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)

ASTM INTERNATIONAL (ASTM)

ASTM A53/A53M	(2018) Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A194/A194M	(2018) Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High-Pressure or High-Temperature Service, or Both
ASTM A307	(2014; E 2017) Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60 000 PSI Tensile Strength
ASTM A518/A518M	(1999; R 2018) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
ASTM B3	(2013) Standard Specification for Soft or Annealed Copper Wire
ASTM B8	(2011; R 2017) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM C94/C94M	(2018) Standard Specification for Ready-Mixed Concrete
ASTM D1248	(2012) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D2028/D2028M	(2015) Cutback Asphalt (Rapid-Curing Type)
ASTM D3381/D3381M	(2018) Standard Specification for Viscosity-Graded Asphalt Binder for Use in Pavement Construction

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE C2	(2017; Errata 1-2 2017; INT 1 2017) National Electrical Safety Code

NACE INTERNATIONAL (NACE)

NACE SP0169	(2015) Control of External Corrosion on Underground or Submerged Metallic Piping Systems
NACE SP0285	(2011) External Corrosion Control of Underground Storage Tank Systems by Cathodic Protection
NACE SP0572	(2001; R 2007) Design, Installation, Operation and Maintenance of Impressed Current Deep Anode Beds

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C119.1	(2016) Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600 Volts
NEMA ICS 6	(1993; R 2016) Industrial Control and Systems: Enclosures
NEMA RN 1	(2005; R 2013) Polyvinyl-Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
NEMA ST 1	(1988; R 1994; R 1997) Specialty Transformers (Except General Purpose Type)
NEMA TC 2	(2013) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2017; ERTA 1-2 2017; TIA 17-1; TIA 17-2; TIA 17-3; TIA 17-4; TIA 17-5; TIA 17-6; TIA 17-7; TIA 17-8; TIA 17-9; TIA 17-10; TIA 17-11; TIA 17-12; TIA 17-13; TIA 17-14; TIA 17-15; TIA 17-16; TIA 17-17) National Electrical Code

U.S. DEPARTMENT OF DEFENSE (DOD)

MIL-I-1361	(1985; Rev C; Notice 1 1991) Instrument Auxiliaries, Electrical Measuring: Shunts, Resistors and Transformers

UNDERWRITERS LABORATORIES (UL)

UL 6	(2007; Reprint Nov 2014) Electrical Rigid Metal Conduit-Steel
UL 44	(2018) UL Standard for Safety Thermoset-Insulated Wires and Cables
UL 83	(2017) UL Standard for Safety Thermoplastic-Insulated Wires and Cables

UL 467	(2013; Reprint Jun 2017) UL Standard for Safety Grounding and Bonding Equipment
UL 486A-486B	(2018) UL Standard for Safety Wire Connectors
UL 489	(2016) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
UL 506	(2017) UL Standard for Safety Specialty Transformers
UL 510	(2017) UL Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013; Reprint Aug 2017) UL Standard for Safety Metallic Outlet Boxes
UL 514B	(2012; Reprint Nov 2014) Conduit, Tubing and Cable Fittings
UL 854	(2004; Reprint Nov 2014) Standard for Service-Entrance Cables

[1.2 Related Requirements

Sections 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS, [33 71 02 UNDERGROUND ELECTRICAL DISTRIBUTION], and, [26 20 00 INTERIOR DISTRIBUTION SYSTEM], apply to this section except as modified herein.

]1.3 SUBMITTALS

****

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

The Guide Specification technical editors have designated those items that require Government approval, due to their complexity or criticality, with a "G". Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For submittals requiring Government approval on Army projects, a code of up to three characters within the submittal tags may be used following the "G" designation to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes

following the "G" typically are not used for Navy, Air Force, and NASA projects.

The "S" following a submittal item indicates that the submittal is required for the Sustainability eNotebook to fulfill federally mandated sustainable requirements in accordance with Section 01 33 29 SUSTAINABILITY REPORTING. Locate the "S" submittal under the SD number that best describes the submittal item.

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

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the "G" designation identifies the office that will review the submittal for the Government.] Submittals with an "S" are for inclusion in the Sustainability eNotebook, in conformance to Section 01 33 29 SUSTAINABILITY REPORTING. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Rectifiers

Insulating flange sets

Anode installation

Test stations

Bonding boxes

Anode junction boxes

Anode vent pipe

Joint bonds

SD-03 Product Data

Rectifiers; G[, [_____]]

Cable and wire; G[, [_____]]

Insulating flange sets

Dielectric unions

Anodes; G[, [_____]]

Test stations

Anode junction boxes

Anode vent pipe; G[, [_____]]

Casing insulators and seals

Reference electrodes; G[, [_____]]

Shunt resistors

Anode backfill; G[, [_____]]

Bonding boxes

SD-07 Certificates

Qualifications of Corrosion Engineer; G[, [_____]]

SD-10 Operation and Maintenance Data

Cathodic protection system, Data Package 5; G[, [_____]]

Rectifier replacement/spare parts list, Data Package 5; G[, [_____]]

Submit in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

SD-11 Closeout Submittals

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

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

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

1.4 SERVICES OF CORROSION ENGINEER

The Contractor shall obtain the services of a Corrosion Engineer to supervise, inspect and test the installation of the cathodic protection system(s). Corrosion Engineer refers to a registered professional engineer with certification or licensing that includes education and experience in cathodic protection of buried or submerged metal structures, or a person certified by the National Association or Corrosion Engineers at the level of Corrosion Specialist or Cathodic Protection Specialist. Such a person shall have not less than [three] [five] [_____] years experience in the cathodic protection of underground [storage tanks] or submerged structures. The contractor shall submit evidence of the qualifications of corrosion engineer to the Contracting Officer for review and approval.

PART 2 PRODUCTS

2.1 ANODES

****

NOTE: The chemical compositions listed are examples only. The actual compositions required shall be determined to provide adequate and economical service.

****

****
*

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

****

[2.1.1 High-Silicon Chromium Bearing Cast Iron

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

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

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

][2.1.2 Graphite

****

NOTE: Maximum allowable current densities for anode surface area are as follows; Seawater: 40.37 amps per square meter 3.75 amps per square foot, Fresh water: 2.69 amps per square meter 0.25 amps per square foot, and Soil (anode placed in backfill): 10.76 amps per square meter 1.0 amps per square foot.

****

Chemical composition as follows:

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

Anode dimensions: [_____] by [_____] mm inches.

]2.1.3   Mixed Metal Oxide Anodes

Mixed metal oxide anodes shall be provided by a firm that is regularly engaged in and has a minimum 5 years experience in manufacturing and applying mixed metal oxide coatings to titanium anode substrates. The mixed metal oxide anodes shall be of the size indicated and shall conform to the following requirements.

2.1.3.1   Conductive Material

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

2.1.3.2   Anode Life Test

Perform an accelerated current capacity life test on every lot of anode wire used to construct the anode as described. The anode wire material shall sustain current densities of 100 ampere per square meter in an oxygen generating electrolyte for 20 years. The manufacturer shall certify that a representative sample taken from the same lot used to construct the anode, has been tested and meets the following criteria.

a. The representative sample shall be 125 mm 5 inch in length and be taken from the lot of wire that is to be used for the anode.

b. The cell containing the anode shall be powered with a constant current power supply for the 30 day test period.

c. The test cell sustains a current density of 10,000 ampere per square meter in a 15 weight percent sulfuric acid electrolyte at 66 degrees C 150 degrees F without an increase in anode to cathode potential of more than 1 volt.

2.1.3.3   Adhesion or Bond Strength Test

Determine the adhesion or bond strength by epoxy bonding a 2.54 mm 100 mils diameter stud to the ceramic coating and measuring the load to failure of either the epoxy or the interface between the coating and the substrate.

2.1.4 Anode Lead Wires

Not less than [No. 8] [No. 6] [_____] AWG stranded copper conductor with [2.8 mm110 mils [_____] thick ASTM D1248, high molecular weight polyethylene (HMWPE) insulation] [an inner jacket of one mm 40 mils [_____] of ethylene chlorotrifluoroethylene insulation covered by an outer jacket of 1.6 m 65 mils [_____] of ASTM D1248, high molecular weight polyethylene (HMWPE)] [a primary insulation of ethylene propylene rubber and an outer jacket of chloro sulphonated polyethylene], [3050] [6100] [_____] mm [10] [20] [_____] feet in length [of sufficient length to extend to junction box without splicing].

2.1.5 Attachment of Anode Lead Wire

Anode lead wires shall be factory installed.

2.1.5.1 End Connected Anode

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

2.1.5.2 Center Connected Anode

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

2.1.5.3 Mixed Metal Oxide Anode Lead Wires

[[Solidly crimp] [and solder] the connection between the anode rod or ribbon and the lead wire. Seal the connection [with two layers of half lapped mastic tape covered with a heat shrinkable sleeve] [in cast epoxy].] [Tin and anneal the copper wire and hydraulically swage the tubular anode onto copper bushings in contact with the wire. Place a 28 mm 1 1/8 inch long copper sleeve, inner diameter slightly larger than the tubular anode outer diameter, over the tube prior to swaging.] Cable to anode contact resistance shall be 0.02 ohms maximum.

2.1.6 Anode Backfill

****

NOTE: The chemical composition listed is for example only. The actual type and composition required shall be determined by the design engineer

to provide adequate and economical service.
****

Calcined petroleum [metallurgical] coal coke breeze having the following analysis:

a. Chemical composition

Fixed carbon	- [99.0] [_____] percent minimum
Ash	- [0.10] [_____] percent
Moisture content	- [0.02] [_____] percent
Sulphur	- [4.29] [_____] percent (maximum)
Volatile matter	- [0.22] [_____] percent

b. Weight: [1045] [768] [1184] [_____] kg per cubic meter [65] [48] [74] lbs per cubic foot

c. Size: 6 mm 1/4 inch maximum diameter [85 percent to pass a 9.5 mm 3/8 inch mesh,] [100 percent to pass 12.5 mm 1/2 inch mesh.]

d. Electrical resistivity: [1] [10] [20] [50] [_____] ohm-cm [maximum] [loose] [tightly compacted]

2.1.7 Gravel

100 percent to pass a 25 mm one inch mesh.

[2.1.8 Anode Centering Device for Deep Anode Ground Beds

Centering device shall be [non-metallic] and capable of maintaining centering in the hole without interfering with other anode lead wiring until completion of backfilling operations.

][2.1.9 Deep Anode Ground Bed Casing

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

Casing shall be [_____] mm inch outside diameter, 3.2 mm 1/8 inch minimum wall thickness black steel pipe, conforming to ASTM A53/A53M, Type E or S, Grade B. The top casing shall be [_____] mm inchoutside diameter, 3.2 mm 1/8 inch minimum wall thickness black steel pipe, conforming to

ASTM A53/A53M, Type E or S, Grade B. The metal casing shall extend no more than 1.5 meters 5 feet below the top of a well cap.

]2.2 ANODE VENT PIPE

NEMA TC 2, Type [EPC-80-PE] [EPC-80-PVC], [38] [_____] mm [1 1/2] [_____] inches in diameter and having [3/16 inch5 mm diameter holes located 150 mm 6 inch apart and at 1.57 rad 90 degrees around the vent pipe] [vertical slits parallel to the pipe longitudinal centerline, 38 mm 1.5 inches long, 0.15 mm 0.006 inch wide, spaced 152 mm 6 inches apart longitudinally and 25 mm one inch apart circumferentially around the vent pipe] along the length of vent tube which is in the coke breeze backfill.

2.3 RECTIFIERS

****

NOTE: Air-cooled rectifiers will be used for most applications in non-corrosive atmospheres. Where highly corrosive atmosphere 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. Variacs should not be used where subjected to corrosive or marine air atmospheres.

****

2.3.1 Transformer

UL 506 and NEMA ST 1, as applicable.

2.3.2 Electrical Ratings

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

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

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

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

2.3.3 Rectifier Stacks

[Silicon] [_____] connected in such a manner as to provide full wave rectification. [Silicon diodes shall be protected by selenium cells or varistors against overvoltage surges and by current limiting devices against overcurrent surges.]

[2.3.4 Enclosure

****

NOTE: Choose this paragraph for air-cooled rectifier enclosures or the paragraph below entitled "Oil Immersed Enclosures." Oil immersed enclosures

shall be used where highly corrosive atmosphere exist. When locating oil immersed rectifiers near buildings, consult with paragraph 3.2.3 of MIL-HDBK 1008C for fire safety requirements.
****

NEMA ICS 6, Type [3] [3X] [4] [4X] [7] [_____], suitable for [wall] [post] [pad] mounting. Enclosure shall include hinged door with [padlock hasp] [key lock, provide [three] [_____] keys]. [Enclosure locks shall be keyed alike.] Fit enclosure with screened openings to provide for cooling by natural convection. Provide holes, conduit knockouts and threaded hubs of sufficient size and location. The cabinet and mounting support shall be [painted] [hot-dipped galvanized] [stainless] steel [according to the manufacturer's standards].

][2.3.5 Oil Immersed Enclosures

Provide enclosures of 11-gage steel or heavier, with an accessible drain plug. The oil level shall be clearly marked. Provide a hinged lid with quick release clamps to secure it in a closed position. Provide a compressive, oil resistant, positive sealing gasket. Base mounting shall have 100 mm 4 inch high channels. Provide an internal terminal board and connections above oil level for monitoring and adjustment. The cabinet and mounting support shall be [painted] [hot-dipped galvanized] [stainless] steel [according to the manufacturer's standards].

]2.3.6 Overload and Short Circuit Protection

UL 489, Molded case circuit breaker, [magnetic] [thermal-magnetic] type.

2.3.7 D.C. Output Control

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

D.C. output voltage shall be adjustable. Transformer taps, [5] [_____] coarse, [[5] [_____] fine.] [Variac.] [_____].

2.3.8 Output Voltage and Current Metering

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

2.3.9 Surge Protection

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

2.3.10 Efficiency

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

2.3.11 Grounding Provisions

NFPA 70 and UL 467 including a grounding terminal in the cabinet. Grounding conductor from terminal to earth grounding system shall be solid or stranded copper not smaller than No. 6 AWG. Earth grounding system shall consist of one or more [copper] [copper clad steel] rods. Ground rods shall be a minimum of 2435 mm 8 feet long.

2.3.12 Shunt Resistors

MIL-I-1361. Resistors shall be located on the rectifier front panel and clearly marked with current and voltage for verification of panel ammeter.

2.3.13 Wiring Diagram

Provide complete wiring diagram of the power unit showing both A.C. supply and D.C. connections to anodes on the inside of the cabinet door. Show and label components.

2.3.14 Rectifier Replacement/Spare Parts List

Provide identification and coverage for all parts of each component, assembly, and accessory of the items subject to replacement in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

2.4 CONDUIT AND CABLE FOR POWER SERVICE AT 600 VOLTS OR LESS

2.4.1 Conduit

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

2.4.2 Cable and Wire Other Than Anode Lead Wires

****

NOTE: Type THW insulation can only be obtained in large quantity. Use of this type insulation is not recommended for small project.

****

Copper conductors conforming to ASTM B3 and ASTM B8. Wires terminating at a rectifier, junction box, or test station shall have cable identification tags. Refer to the paragraph entitled "Anode Lead Wires" [_____] for anode lead wires.

2.4.2.1 AC Power Supply Wiring

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

2.4.2.2 Rectifier DC Negative (Structure) Cable(s)

ASTM D1248, High Molecular Weight Polyethylene (HMWPE) insulation, stranded copper conductors, gage (AWG) as indicated.

[2.4.2.3 Rectifier DC Positive (Anode) Header Cable(s)

ASTM D1248, High Molecular Weight Polyethylene (HMWPE) insulation, stranded copper conductors, gage (AWG) as indicated. Refer to the paragraph entitled "Anode Lead Wires" [_____] for anode lead wires.

]2.4.2.4 Continuity Bond Cables

ASTM D1248, High Molecular Weight Polyethylene (HMWPE) insulation, stranded copper conductors, gage (AWG) as indicated. Do not use bare copper wire for joint continuity bonds.

2.4.3 Cable and Wire Identification Tags

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

2.4.4 Wire Connectors

[UL 486A-486B.] [Solderless copper crimp connections.] [Exothermic weld.]

2.4.5 Insulating Tape

UL 510.

2.4.6 Underground Splices

****

NOTE: Splices and damaged anode lead wire insulation are a common cause of premature failure. Splices are not normally allowed except under certain circumstances. If splices are allowed, select the appropriate option.

****

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

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

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

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

2.4.7 Buried Cable Warning and Identification Tape

Polyethylene tape, manufactured for warning and identification of buried cable and conduit. Tape shall be [75] [_____] mm [3] [_____] inches wide, [Yellow] [_____] in color and read "Caution Buried Cable Below" or similar. Color and lettering shall be permanent and unaffected by moisture or other substances in backfilling.

2.5 ANODE JUNCTION BOXES AND TEST STATIONS

2.5.1 Flush Mounted Type

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

2.5.2 Post Top Mounted Type

NEMA ICS 6. Metallic or non-metallic with terminal board, [5] [8] [_____] terminal posts and lockable lid. A non-metallic enclosure shall be high impact strength molded plastic. The unit shall be of standard design, manufactured for use as a cathodic protection test station, complete with cover, terminal board, shunts, and brass or Type [304] [316] stainless steel hardware. The terminal board shall be removable for easy access to wires. The test station shall be mounted atop 1830 mm 6 foot long polyethylene conduit with anchor.

2.5.3 Wall Mounted Type

NEMA ICS 6, Type [3R] [4X] [_____] enclosure with [clamped cover] [Type [304] [316] stainless steel hinges and [clamped] [latched] cover] [and padlocked hasp]. Enclosure shall be of [galvanized steel] [painted steel] [aluminum] [fiberglass] [non-metallic] construction with terminal board and labeled with nameplate. Provide nameplate in accordance with Section 26 00 00.00 20 BASIC ELECTRICAL MATERIALS AND METHODS. Enclosure mounting posts shall be [galvanized steel pipe,schedule [40] [80] [_____]], [wood post, full length pressure treated with pentachlorophenol] [as indicated]. Mount enclosure 1066 mm 42 inches above finished grade [as indicated].

2.5.4 Terminal Boards

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

Anode lead wire:	black
Structure lead wire:	white
Sodium sulfate:	red

]

2.5.5 Shunt Resistors

[MIL-I-1361.] [0.01] [_____] ohm, [6] [_____] ampere, accuracy plus or minus one percent, [manganin wire] [_____] type.

2.5.6 Pavement Insert

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

2.5.7 Cast-In-Place Concrete

Flush mount type test stations, bonding boxes, and anode junction boxes shall be centered in a 460 by 460 by 102 mm 18 by 18 by 4 inch concrete slab. Concrete shall be 20 Mpa 3000 psi minimum ultimate 28-day compressive strength with 25 mm 1-inch minimum aggregate conforming to [ASTM C94/C94M] [Section 03 30 00 CAST-IN-PLACE CONCRETE].

2.6 INSULATING FLANGE SETS

****

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

****

Provide full-faced gaskets, insulating sleeves and washers, and steel washers. Provide flange sets rated for operation at the rated pressure and temperature of the flanges.

2.6.1 Gaskets

****

NOTE: Do not use asbestos materials.

****

ASME B16.21. [Neoprene faced phenolic] [Laminated phenolic] material for operations at [862] [_____] kPa [125] [_____] psi and [232] [_____] degrees C [450] [_____] degrees F.

2.6.2 Insulating Washers and Sleeves

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

2.6.3 Washers

Steel, cadmium plated, to fit within the bolt facing on the flange.

2.7 DIELECTRIC UNIONS

****

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

****

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

2.8 BONDING AND GROUNDING EQUIPMENT

UL 467.

2.9 ELECTRICAL INSULATING COATINGS

[Heat-shrinkable tape] [Conformable water tight sealant having dielectric strength not less than 15 kV for a 3 mm 1/8 inch thick layer].

****

NOTE: Rectifiers shall be pad or post mounted. Select the appropriate paragraph.

****

[2.10 CONCRETE RECTIFIER PAD

****

NOTE: Provide detail on the drawings.

****

Dimensions, conduit locations, and anchor bolt location [as indicated] [in accordance with] the manufacturer's drawings for the equipment furnished.

2.10.1 Concrete

20.67 MPa 3000 psi concrete conforming to [ASTM C94/C94M] [Section 03 30 00 CAST-IN-PLACE CONCRETE.]

][2.11 RECTIFIER MOUNTING POST

[Galvanized steel pipe, Schedule [40] [80]], [wood post, full length pressure treated with pentachlorophenol].

]2.12 CASING INSULATORS AND SEALS

Casing insulators shall have a minimum [305] [_____] mm [12] [_____] inch band width, [constructed of heat fused plastic coated steel] [_____] and multi-segmented to attach firmly around the pipe. Casing end seals shall be S-shaped rubber seals with stainless steel straps.

2.13 PERMANENT REFERENCE ELECTRODES

Permanent reference electrodes shall be [copper copper-sulfate] [silver silver-chloride] [zinc] specifically manufactured for [underground] [marine] use, [31.75] [_____] mm [1 1/4] [_____] inch diameter, by [255] [_____] mm [10] [_____] inches long, [plastic [_____] tube with an ion trap to minimize contamination of the cell] [, and a minimum surface sensing area of [_____] square centimeters[_____] square inches]. [The cell shall be prepackaged by the manufacturer with a backfill material as recommended by the manufacturer.] Provide cells with No. [10] [12] [_____] AWG, [THHN] [_____] cable of sufficient length to extend to the [test station] [junction box] without splicing. Reference electrodes shall have a minimum 15 year life, stability of plus or minus 5 millivolts under 3 microamp load, and an initial accuracy of plus or minus 10 millivolts referenced to a calibrated portable reference electrode.

2.14 STEEL FLANGES AND BOLTING

2.14.1 Steel Flanges

ASME B16.5 [667.5] [1335] [_____] N [150] [300] [_____] lb.

2.14.2 Bolting

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

2.15 EXOTHERMIC WELD KITS

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

PART 3 EXECUTION

3.1 ANODE INSTALLATION

[IEEE C2] [NFPA 70].

3.1.1 Anodes and Lead Wires

Provide anodes and lead wires as follows [and in accordance with NACE SP0572].

****

NOTE: Select the applicable paragraph(s) from the following dependent upon selection of vertical or horizontal anodes. Deep well anode beds may also be used. Designer shall select anode and installation procedures for specific site. Provide detail on the

drawings.
****

[3.1.1.1 Vertical Anodes

a. Excavation for anodes: Excavate hole to [a minimum 75 mm 3 inches larger than the packaged anode diameter.] [the diameter indicated.] [1220 mm4 feet deeper than the anode length.] [the depth indicated.]

b. Excavation for wire trench: Excavate lead [and main feeder] wire trenches to [the depth indicated] [not less than [455] [610] mm[18] [24] inches deep], [[150] [_____] mm[6] [_____] inches wide] [width as indicated].

c. Lifting anodes: Do not lift or support anode by the lead wire. Exercise care to preclude damaging the anode and the lead wire insulation.

d. Installing anodes: [Place 305 mm 12 inches of coke breeze in the hole and tamp well. Center the anode in the hole and place 305 mm 12 inches of additional coke breeze and tamp well taking care not to strike and damage the anode lead wire. Repeat sequence until coke breeze is 305 mm 12 inches above the anode.] [Center the canister anode in the hole. Completely fill the annular space between the canister and the wall of the hole with a slurry of stone free earth.] [Place a vent pipe vertically above the anode. Cut the pipe to sufficient length to extend from 75 mm 3 inches within the coke breeze to 75 mm 3 inches below finish grade. Place gravel around the vent pipe to a level 150 mm 6 inches below finish grade.] Fill the remaining excavation with soil and tamp.

e. Installing lead wires: Provide anodes with lead wires of sufficient length to extend to the anode junction box without splicing. Cover the lead [and main feeder] wire trench bottom with a 75 mm 3 inch layer of sand or stone free earth. Center wire on the backfill layer. Handle to eliminate damage to the cable and insulation, do not stretch or kink the conductor. Place backfill over wire in layers not exceeding 150 mm 6 inches deep, compact each layer thoroughly. Do not place tree roots, wood scrap, vegetable matter and refuse in the backfill.

****
NOTE: Splices and damaged anode lead wire insulation are a common cause of premature failure. Splices are not normally allowed except under certain circumstances. If splices are allowed, select the "Anode lead to main feeder connections" option.
****

f. Splices not allowed: Splices, or repairs to damaged anode lead wire insulation are not allowed. Install anode lead wires back to the anode junction box as indicated in the drawings. [Anode lead to main feeder connections: Make connections as follows:

****
NOTE: Choose one of the following options.
****

[(1) Remove insulation to expose approximately 50 mm 2 inches of each conductor.

(2) Make connection between conductors using solderless crimp connector or exothermic weld.

(3) Cover connection with uncured butyl rubber tape to provide filler wrap.

(4) Apply four layers of half-lapped neoprene tape, extend the tape over the cable insulation.

(5) Apply two layers of half-lapped pressure sensitive polyethylene or polyvinyl chloride tape.]

[(1) Remove insulation to expose approximately 50 mm 2 inches of each conductor.

(2) Make connection between conductors using solderless crimp connector or exothermic weld.

(3) Cover connection with pre-manufactured splice kit.]]

g. Anode junction box. Mark each of the wires terminating in the junction box. Install anode junction box as shown in the drawings [prior to pouring the concrete slab].

h. Installing lead wires. Connect anode lead wires to the appropriate terminals in the anode junction box.

][3.1.1.2 Horizontal Anodes

a. Excavation for anodes: Excavate anode trenches to [the depth indicated, 610 mm two feet longer than the anode, 305 mm one foot wide] [the depth, length, and width indicated].

b. Excavation for wire trench: Excavate lead [and main feeder] wire trenches to [the depth indicated] [not less than [455] [610] mm [18] [24] inches deep], [[150] [_____] mm[6] [_____] inches wide] [width as indicated].

c. Lifting anodes: Do not lift or support anode by the lead wire. Exercise care to preclude damaging the anode and the lead wire insulation.

d. Installing anodes: Place [100] [_____] mm [4] [_____] inches of coke breeze in the anode trench and tamp well. Center the anode in the trench and cover with coke breeze to provide a minimum [100] [_____] mm [4] [_____] inch cover over the anode. Tamp the coke breeze firm taking care not to strike and damage the anode lead wire. [Place a vent pipe vertically above the anode. Cut the pipe to sufficient length to extend from 75 mm 3 inches within the coke breeze to 75 mm 3 inchesbelow finish grade. Place gravel around the vent pipe to a level 150 mm 6 inches below finish grade.] Fill the remaining excavation with soil and tamp.

e. Installing lead wires: Provide anodes with lead wires of sufficient length to extend to the anode junction box without splicing. Cover the lead [and main feeder] wire trench bottom with a 75 mm 3 inch layer of sand or stone free earth. Center wire on the backfill layer. Handle to prevent damage to the cable and insulation, do not stretch or kink the conductor. Place backfill over wire in layers not exceeding 150 mm 6 inches deep, compacting each layer thoroughly. Do not place tree roots, wood scrap, vegetable matter, and refuse in the backfill. Place cable warning tape, within [455] [_____] mm [18] [_____] inches of finished grade, above buried cable and conduit.

****
NOTE: Splices and damaged anode lead wire insulation are a common cause of premature failure. Splices are not normally allowed except under certain circumstances. If splices are allowed, select the "Anode lead to main feeder connections" option.
****

f. Splices not allowed: Splices, or repairs to damaged anode lead wire insulation are not allowed. Install anode lead wires back to the anode junction box as indicated in the drawings. [Anode lead to main feeder connections: Make connectors as follows:

****
NOTE: Choose one of the following options.
****

[(1) Remove insulation to expose approximately 50 mm 2 inches of each conductor.

(2) Make connection between conductors using solderless crimp connector or exothermic weld.

(3) Cover connection with uncured butyl rubber type to provide filler wrap.

(4) Apply four layers of half-lapped neoprene tape, extend the tape over the cable insulation.

(5) Apply two layers of half-lapped pressure sensitive polyethylene or polyvinyl chloride tape.]

[(1) Remove insulation to expose approximately 50 mm 2 inches of each conductor.

(2) Make connection between conductors using solderless crimp connector or exothermic weld.

(3) Cover connection with pre-manufactured splice kit.]]

g. Anode junction box. Mark each of the wires terminating in the junction box. Install anode junction box as shown in the drawings [prior to pouring the concrete slab].

h. Installing lead wires. Connect anode lead wires to the appropriate terminals in the anode junction box.

][3.1.1.3 Deep Well Anode Ground beds

a. Drilling of anode well. Drilling of the anode well shall be accomplished by a qualified well driller. Submit documentation of experience to the Contracting Officer. Drill a hole [254] [305] [_____] mm [10] [12] [_____] inches in diameter to the depth indicated using rotary bit equipment designed specifically for this purpose. Select the type and consistency of drilling fluids to be consistent with soil characteristics. The use of temporary well casings may be necessary. Remove all temporary casings upon completion of the installation.

b. Excavation for wire trench. Excavate anode header cable [_____] wire trenches to [the depth indicated] [not less than [455] [610] mm [18] [24] inches deep], [[150] [_____] mm[16] [_____] inches wide] [width as indicated].

c. Installing anodes. Do not lift or support anode by the lead wire. Exercise care to preclude damaging the anode and the lead wire insulation. Attach the anode centralizers to the anodes. [Place the vent pipe in the hole as indicated prior to installing the anodes. Install the anodes in the hole at the depths indicated and supported in place using a method that does not suspend the anodes by the lead wire.] [Strap the [anodes] [anode assembly] to the vent pipe spaced as indicated on the drawings. Lower the anode/vent pipe assembly into the hole.] [Label and coil the excess anode lead wire at the top of the casing].

d. Coke backfill. Pump the coke back fill into the hole through a separate removable tube with the tip at the bottom of the hole. Pumping operations shall be continuous. Maintain a continuous supply of fluidized coke at the pump suction until coke is filled to the top of the hole. Allow the coke to settle for [24] [_____] hours. Verify the level of coke and provide additional as necessary until the level of coke is not lower than that indicated in the drawings.

e. [Casing. Install well head casing as indicated. Seal the annular space between the casing and earth with cement grout. Seal the top of the anode well as shown on the drawings.]

f. Anode well access box. Place the anode well access box around the top of the casing, and pour the concrete slab around the box as indicated.

g. Anode junction box. Install anode junction box as shown in the drawings [prior to pouring the concrete slab].

h. Installing lead wires. Provide anodes with lead wires of sufficient length to extend to the anode junction box without splicing. Splices, or repairs to damaged anode lead wire insulation are not allowed. Mark each of the wires terminating in the junction box. Connect anode lead wires to the appropriate terminals in the anode junction box.

i. Anode header cable. Provide anodes header cable of sufficient length to extend to the anode junction box without splicing. Splices, or repairs to damaged anode header cable wire insulation are not allowed. Cover the anode header cable trench bottom with a 75 mm 3 inch layer of sand or stone free earth. Center wire on the backfill layer. Handle cable to prevent damage to the cable and insulation, do not stretch or kink the conductor. Place backfill over wire in layers not exceeding 150 mm 6 inches deep, compact each layer thoroughly. Do not place tree roots, wood scrap, vegetable matter and refuse in the backfill. Connect the anode header cable to the appropriate terminal in the anode junction box.

]3.1.2 Wire-To-Structure Connections

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

3.1.2.1 Safety Precautions Around Fuel Facilities

Contractor shall take proper safety precautions prior to and during welding to live fuel pipelines [tanks]. Contractor shall notify the activity Fuel Office via the Contracting Officer a minimum of three days before performing exothermic welding to live fuel lines. Exothermic welding shall be conducted with fuel flowing through the pipeline to eliminate vapor spaces within the pipe and to dissipate the heat on the pipe. Exothermic weld charges for connections to fuel lines shall be limited to a maximum 15 gram charge to prevent burning through the pipe wall. Exothermic weld connections shall be spaced a minimum of150 mm 6 inches apart. In the event of an unsuccessful weld, the new weld location shall be located a minimum of 6 inches from the unsuccessful weld and any other existing welds. Contractor shall obtain the services of a certified Marine Chemist or Certified Industrial Hygienist [to monitor the construction site during exothermic welding work and certify that the area is free of flammable vapors and otherwise safe for work.] [to approve the contractor's exothermic welding safety procedures. Results of this consultation shall be included in the Contractor's Daily Report.]

3.1.3 Rectifiers

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

3.1.4 Test Stations [and Permanent Reference Electrodes]

Locate test stations [and permanent reference electrodes] [as indicated.] as follows:

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

b. At insulating joints.

c. At both ends of casings.

d. Where the pipe crosses any other metal pipes.

e. Where the pipe connects to an existing old piping system not under cathodic protection.

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

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

3.1.4.1   Permanent Reference Electrode Calibration and Installation

Provide [prepackaged] [copper copper-sulfate] [silver-silver chloride] [zinc] reference electrode(s) as indicated in the drawings. Prior to installation, soak the [prepackaged] reference electrode in a container of potable water for 30 minutes. Do not use seawater [except for silver-silver chloride electrodes intended for use in seawater]. Calibrate the permanent reference electrode in the presence of the contracting officer or his approved representative by measuring the potential difference between the permanent reference electrode and an independent (portable) calibrated reference electrode placed in the water adjacent to the permanent reference electrode. [Potential differences between the two electrodes of the same generic type should not exceed [10] [15] millivolts when the [sensing windows of the] two electrodes being compared are not more than 2 mm 1/6 inch apart but not touching.] [Zinc permanent reference electrodes should be within the range of minus 1000 to minus 1150 millivolts when calibrated with an independent (portable) calibrated copper-copper sulfate reference electrode with the two electrodes being not more than 2 mm 1/6 inch apart but not touching.] Permanent reference electrodes not within these potential differences shall be removed from the construction site by the end of the day and replaced at the contractor's expense. [Prior to completely backfilling over reference electrodes, again verify the accuracy of the reference electrode.] The testing provision shall also apply to replacement reference electrodes as well.

3.1.5   Bonding Boxes

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

3.1.6   Insulating Flange Sets

[Provide insulating flange sets aboveground or within manholes as indicated.] [Locate insulating flanges on lines entering buildings at least 305 mm 12 inches above grade or floor level.] [Cut piping and provide flanges into place. Carefully align flange bolt holes and weld flange to pipe in accordance with ASME B16.25.] [Electrically isolate pipelines entering buildings from the structure wall either below or above ground with an electrically isolating wall sleeve.] Provide insulating flange sets into place without springing or forcing. Carefully install flange bolt sleeves to avoid damage to the sleeves. [Cover insulating flanges with an electrically insulating coating.]

3.1.7   Dielectric Unions

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

3.1.8 Joint Bonds

Provide joint bonds on metallic pipe to and across buried flexible couplings, mechanical joints, flanged joints [except at places where insulating joints are specified] and at joints not welded or threaded to provide electrical continuity. Conform to the safety precautions of paragraph [_____] when welding around fuel facilities. Check and verify adherence of the bond to the substrate for mechanical integrity by striking the weld with a 908 gram 2 pound hammer.

3.1.9 Casings, Insulation, and Seals

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

3.1.10 Reconditioning of Surfaces

****

NOTE: On projects having site work provided by DIVISION 2, coordinate the requirements for reconditioning of surfaces with the appropriate section(s).

****

3.1.10.1 Restoration of Sod

Restore unpaved surfaces disturbed during the installation of anodes and wires to their original elevation and condition. Preserve sod and topsoil carefully and replace after the backfilling is completed. Where the surface is disturbed in a newly seeded area, re-seed the area with the same quality and formula of seed as that used in the original seeding.

3.1.10.2 Restoration of Pavement

Patch pavement, sidewalks, curbs and gutters where existing surfaces are removed for construction. Saw cut pavement edges. Graded aggregate base course shall have a maximum aggregate size of 35 mm 1 1/2 inches. Prime base course with [liquid asphalt, ASTM D2028/D2028M, Grade RC-70] [_____] prior to paving. Match base course thickness to existing but shall not be less than 150 mm 6 inches. Asphalt aggregate size shall be 12.7 mm 1/2 inch, asphalt cement shall [conform to ASTM D3381/D3381M, Grade AR-2000] [_____]. Match asphalt concrete thickness to existing but shall not be less than 50 mm 2 inches. Repair portland cement concrete pavement, sidewalks, curbs, and gutters using 20.67 MPa 3,000 psi concrete conforming to [ASTM C94/C94M] [Section 03 30 00 CAST-IN-PLACE CONCRETE]. Match existing pavement, sidewalk, curb, and gutter thicknesses.

3.2 FIELD QUALITY CONTROL

Field tests shall be witnessed by the Contracting Officer or his designated representative. Advise the Contracting Officer [5] [_____] days prior to performing each field test. Quality control for the cathodic protection system shall consist of the following:

a. Initial field testing by the contractor upon construction.

b. Government Field Testing after Contractor initial field test report submission.

c. Warranty period field testing by the Contractor.

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

****

NOTE: Additional testing may be required, based upon the specific project or design. All tests listed below may not be required. Designer should consider the project requirements for selection of test procedures.

****

3.2.1 Testing

3.2.1.1 Destructive Testing

Contractor shall perform the tests in the presence of the Contracting Officer. Contractor shall include the cost of an additional anode [of each different type] with the longest lead wire for the destructive test in his bid. One completed [prepackaged] anode of each type with lead wires shall be chosen at random for destructive testing and shall be submitted to a static pull test. Anode lead wire connections of anodes shall have sufficient strength to withstand a minimum tensile load of [1335] [_____] N [300] [_____] pounds. [The anode shall also be cut into sections and/or broken with a sledge hammer to verify conformance with this specification. Such items as anode-to-wire connection, complete encapsulation of the wire connector, and wire to anode electrical resistance shall be checked.] [Failure of the test anode to conform to this specification can be cause for rejecting all anodes from the same lot as the test anode. The contractor shall mark all rejected anodes on the ends with a 150 mm 6 inches high "X" using yellow spray paint. Failed anodes shall be removed from the job site by the end of the day. The contractor shall replace any rejected anodes at his expense. The destructive testing provision shall also apply to replacement anodes as well.]

3.2.1.2 Wire for Power Service

Test wire for power service at 600 volts or less to determine that the wiring system and equipment are free from short circuits and grounds [by a minimum of two megohms]. Perform the test with a megohm meter having a 500-volt rating.

3.2.1.3 Initial Cathodic Protection System Field Testing

The systems shall be tested and inspected by the Contractor's corrosion engineer in the presence of the Contracting Officer's corrosion protection engineer or an approved representative. Record test data, including date, time, and locations of testing and submit report to the Contracting Officer. Contractor shall correct, at his expense, all deficiencies in the materials and installation observed by these tests and inspections. Contractor shall pay for retests made necessary by the corrections. Testing shall include the following measurements:

a. Base potential tests: At least [one week] [24 hours] [_____] after [backfilling of the pipe] [installation of the structure to be protected] [initial operation of structures containing fluids] [_____] , but before energizing of the cathodic protection system, measure the base (native) [structure-to-electrolyte] [pipe-to-soil] potentials of the [pipe [and the casings]] [structure]. Perform measurements at anode junction boxes, test stations and other locations suitable for test purposes (such as service risers or valves) at intervals not exceeding [30] [122] [_____] meters [100] [400] [_____] feet with readings at each end point and the midpoint as a minimum. The locations of these measurements shall be identical to the locations specified for measuring energized [structure-to-electrolyte] potentials. Use the same measuring equipment that is specified for measuring protected potential measurements.

[For underground storage tanks, take a minimum of three measurements with the reference electrode located as follows:

(1) Directly over the longitudinal and transverse centerlines of the tank at intervals not exceeding the diameter of the tank and to a distance from the tank of two times the tank diameter.

(2) At points directly around the circumference of the tank.]

b. Permanent reference electrode calibration: Verify calibration of the reference electrode by measuring the potential difference between the permanent reference electrode and an independent (portable) calibrated reference electrode placed in the soil or water adjacent to or as close as practicable to the permanent reference electrode. [Potential differences between the two electrodes of the same generic type should not exceed [10] [15] millivolts.] [Zinc permanent reference electrodes should be within the range of minus 1000 to minus 1150 millivolts when calibrated with a copper-copper sulfate reference electrode.] Permanent reference electrodes not within these potential differences shall be removed from the construction site by the end of the day and replaced at the contractor's expense. The testing provision shall also apply to replacement reference electrodes as well.

c. Insulation joint testing: Perform insulation testing at each insulating joint or fitting [prior to burying the joint or fitting] before and after the cathodic protection system is energized. Before energizing, test using an insulation checker. After energizing, test the insulation by measuring the potential shift on both sides of the insulating joint. This testing shall demonstrate that no metallic contact or short circuit exists between the two insulated sections of the pipe. Report and repair defective insulating fitting at the Contractor's expense.

d. Electrical continuity testing: Perform electrical continuity testing for joint bonded pipe prior to backfilling of the pipe. [Circulate current through the pipe and compare the measured resistance to the theoretical resistance of the pipe and bond cables. The resistance measured shall not exceed 150 percent of the theoretical resistance.]

e. Rectifier system testing: Upon completion of the installation, "Baseline Potential Tests", "Insulation Joint Tests", and "Electrical Continuity Tests", energize and adjust each rectifier. Measure D.C. outputs of the rectifier and current outputs [of each anode] [of associated ground bed] at different rectifier settings. Measure the current outputs across the installed shunts. Verify these readings using portable, calibrated meters and shunts. This testing shall demonstrate if the rectifier system is capable of functioning properly as required to provide effective cathodic protection.

f. Pipe casing testing: Before final acceptance of the installation, test the electrical insulation of the carrier pipe from casings and correct any short circuits.

g. Energized potential tests: With the entire cathodic protection system put into operation for at least [one week] [24 hours] [_____], measure pipe-to-soil potentials along the [pipeline [and at all casings]] [structure] using a portable [copper/copper sulfate] [silver silver-chloride] [and all permanent] reference electrode(s) and a voltmeter having an input impedance of not less than 10 megohms. The locations of these measurements shall be identical to the locations used for the base potential measurements.

h. Interference testing: Perform interference testing with respect to any crossing and nearby foreign pipelines in cooperation with the owner of the related pipelines. The testing shall verify that the subject cathodic protection system does not have a deleterious effect on the foreign pipelines, and vice versa. Prepare a full report of the tests, giving all details including remedial actions taken or recommendations to correct noted interference problems.

3.2.1.4 Initial Cathodic Protection System Field Test Report

The contractor shall submit a field test report of the cathodic protection system. All structure-to-electrolyte measurements, including initial potentials and anode outputs, shall be recorded on applicable forms. Identification of test locations, test station and anode test stations shall coordinate with the as-built drawings and be provided on system drawings included in the report. The contractor shall locate, correct, and report to the Contracting Officer any short circuits encountered during the checkout of the installed cathodic protection system.

****

NOTE: The requirements of paragraph entitled "Government Field Testing" are required for cathodic protection projects in the NAVFAC LANT area. The designer should verify their applicability to projects outside the NAVFAC LANT area with the appropriate EFD corrosion program manager.

****

3.2.1.5 Government Field Testing

The government corrosion [engineer, NAVFAC LANT Code 404] [program manager, NAVFAC LANT Code 1614C] shall review the Contractor's initial field testing report. Approximately four weeks after receipt of the Contractor's initial test report, the system will be tested and inspected in the Contractor's presence by the government corrosion [engineer, NAVFAC LANT Code 404] [program manager, NAVFAC LANT Code 1614C]. The Contractor shall correct, at his expense, materials and installations observed by these tests and inspections to not be in conformance with the plans and specifications. The Contractor shall pay for all retesting done by the government engineer made necessary by the correction of deficiencies.

****

NOTE: For cathodic protection projects in the

NAVFAC LANT area, select the appropriate NAVFAC LANT6 options for paragraphs entitled "One Year Warranty Period Testing" and "Final Field Testing."
****

3.2.1.6 One Year Warranty Period Testing

The Contractor shall inspect, test, and adjust the cathodic protection system [quarterly] [semi-annually] [_____] for one year, [4] [2] [_____] interim inspections total, to ensure its continued conformance with the criteria outlined below. The performance period for these tests shall commence upon the completion of all cathodic protection work, including changes required to correct deficiencies identified during initial testing, and preliminary acceptance of the cathodic protection system by the Contracting Officer. Copies of the One Year Warranty Period Cathodic Protection System Field Test Report, including field data, and certified by the Contractor's corrosion engineer shall be submitted to the Contracting Officer, the activity, and the geographic Engineering Field Division corrosion [protection program manager] [engineer, NAVFAC LANT Code 404] [protection program manager, NAVFAC LANT Code 1614C].

3.2.1.7 Final Field Testing

Conduct final field testing of the cathodic protection system utilizing the same procedures specified under, "Initial Field Testing of the Galvanic Cathodic Protection Systems". The Contractor shall inspect, test, and adjust the cathodic protection system after one year of operation to ensure its continued conformance with the criteria outlined below. The performance period for these tests shall commence upon the completion of all cathodic protection work, including changes required to correct deficiencies identified during initial testing, and preliminary acceptance of the cathodic protection system by the Contracting Officer. Copies of the Final Cathodic Protection System Field Test Report, certified by the Contractor's corrosion engineer shall be submitted to the Contracting Officer and the geographic Engineering Field Division corrosion [protection program manager] [engineer, NAVFAC LANT Code 404] [protection program manager, NAVFAC LANT Code 1614C] for approval, and as an attachment to the operation and maintenance manual in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

3.2.2 Criteria for Cathodic Protection

Conduct in accordance with [NACE SP0169] [NACE SP0285]. Criteria for determining the adequacy of protection shall be selected by the corrosion engineer as applicable:

****
NOTE: The following criteria are applicable only to iron and steel structures. Refer to NACE SP0169 for appropriate criteria for other metal structures. Not all criteria may be readily applicable to the type of CP system(s) being designed, and the designer should select only the applicable criteria.
****

a. A negative voltage of at least 0.85 volt (850 millivolts) as measured between the structure surface and a saturated copper-copper sulfate reference electrode contacting the earth [electrolyte]. Determination of this voltage is to be made with the protective current applied to the [structure] [tank] [pipeline] for a minimum of [24] [_____] hours. Voltage drops must be considered for valid interpretation of this voltage measurement. The method of voltage drop consideration shall be identified by the Contractor's corrosion engineer and approved by the Government corrosion engineer.

b. A negative polarized potential of at least 0.85 volt (850 millivolts) as measured between the structure surface and a saturated copper-copper sulfate reference electrode contacting the earth [electrolyte]. Determination of this voltage is to be made after the protective current has been applied to the [structure] [tank] [pipeline] for a minimum of [24] [_____] hours.

c. A minimum polarization voltage shift of 100 mV measured between the structure surface and a saturated copper-copper sulfate reference electrode contacting the earth [electrolyte]. This voltage shift shall be determined by interrupting the protective current and measuring the polarization decay. At the instant the protective current is interrupted ("instant off"), an immediate voltage shift will occur. The voltage reading just after the immediate shift shall be used as the base reading from which to measure the polarization decay. The polarization decay shall be the difference between the base reading and a voltage measurement made [24] [48] [_____] hours after the interruption of protective current.

3.3 DEMONSTRATION

3.3.1 Instructing Government Personnel

****

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

****

During the warranty testing and at a time designated by the Contracting Officer, make available the services of a technician regularly employed or authorized by the manufacturer of the Cathodic Protection System for instructing Government personnel in the proper operation, maintenance, safety, and emergency procedures of the Cathodic Protection System. The period of instruction shall be not less than [one] [_____] but not more than [two] [_____] 8-hour working day[s]. Conduct the training at the jobsite or at another location mutually satisfactory to the Government and the Contractor. The field instructions shall cover all of the items contained in the operation and maintenance manual.

3.4 SCHEDULE

Some metric measurements in this section are based on mathematical conversion of English unit measurements, and not on metric measurement commonly agreed to by the manufacturers or other parties. The English and metric units for the measurements shown are as follows:

Products	English Units	Metric Units
a. Reference Electrodes		
Diameter	1 1/4 inches	31.75 mm
Length	10 inches	255 mm
b. Terminal Board		
(phenolic plastic)	1/8 inch	3 mm
thickness	1/4 inch	6 mm

-- End of Section --