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USACE / NAVFAC / AFCEC / NASA **UFGS-26 42 22.00 20 (January 2008)**

Preparing Activity: NAVFAC **Superseding UFGS-26 42 22.00 20 (April 2006)**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated July 2014

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DIVISION 26 - ELECTRICAL

SECTION 26 42 22.00 20

CATHODIC PROTECTION SYSTEM FOR STEEL WATER TANKS

01/08

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SECTION 26 42 22.00 20

CATHODIC PROTECTION SYSTEM FOR STEEL WATER TANKS
01/08

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NOTE: This guide specification covers the requirements for steel water tank cathodic protection systems using impressed current systems and galvanic anodes.

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

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

Comments, suggestions and recommended changes for this guide specification are welcome and should be submitted as a Criteria Change Request (CCR)**.**
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The Preparing Activity, NAVFAC LANT, has significant experience and technical expertise in the area of field testing and commissioning of new systems. If Reach-back support is required, the technical representative (electrical engineer) editing this document for a specific project shall contact the NAVFAC Atlantic Capital Improvements Electrical Engineering (CIEE) office for consultation during the design stage of the project and include the bracketed option in the 'Submittals' section.
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NOTE: One of the major factors influencing selection of the type of cathodic protection system is the resistivity of the water involved. When the water resistivity is higher than 10,000 ohm-cm,

impressed current systems are usually used. Other considerations include availability of electric power and the costs of installation, operation and maintenance. Where relatively small amounts of current are required or where energy is not readily available and water resistivity is low, galvanic anodes may be applied. Where relatively large currents are required and reasonable access to power is available, the impressed current system will generally be found to be more economical. 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 Standard; RPO-388, "Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Tanks", and RP0-196, "Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Tanks."

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

1. Dimensions of tank, including riser (if tank is elevated), structural supports and overflow.

2. Locations of all anodes, reference electrodes, junction boxes, test boxes, rectifiers, power connections, wire and conduit.

3. Installation details for anodes and rectifiers.

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

5. Remote indicating or control requirements.

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PART 1 GENERAL

1.1 REFERENCES

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

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

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.
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The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

ASTM INTERNATIONAL (ASTM)

ASTM A518/A518M	(1999; R 2012) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
ASTM B3	(2013) Standard Specification for Soft or Annealed Copper Wire
ASTM B8	(2011) Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B843	(2013) Standard Specification for Magnesium Alloy Anodes for Cathodic Protection
ASTM D1248	(2012) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
ASTM D709	(2013) Laminated Thermosetting Materials

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 100	(2000; Archived) The Authoritative Dictionary of IEEE Standards Terms
IEEE 81	(2012) Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System
IEEE C135.30	(1988) Standard for Zinc-Coated Ferrous Ground Rods for Overhead or Underground Line Construction
IEEE C2	(2012; Errata 2012; INT 1-4 2012; INT 5-7 2013) National Electrical Safety Code

NACE INTERNATIONAL (NACE)

NACE SP0196	(2011) Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks
NACE SP0388	(2001; R 2014) Impressed Current Cathodic Protection of Internal Submerged Surfaces

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C119.1	(2011) Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600 Volts
NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA ICS 6	(1993; R 2011) 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	(2014; AMD 1 2013; Errata 1 2013; AMD 2 2013; Errata 2 2013; AMD 3 2014; Errata 3 2014) 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 44	(2014) Thermoset-Insulated Wires and Cables
UL 467	(2007) Grounding and Bonding Equipment
UL 486A-486B	(2013; Reprint Feb 2014) Wire Connectors
UL 489	(2013; Reprint Mar 2014) Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
UL 506	(2008; Reprint Oct 2013) Specialty Transformers
UL 510	(2005; Reprint Jul 2013) Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013) Metallic Outlet Boxes
UL 514B	(2012) Conduit, Tubing and Cable Fittings
UL 6	(2007; reprint Nov 2010) Electrical Rigid Metal Conduit-Steel
UL 83	(2014) Thermoplastic-Insulated Wires and

Cables

UL 854 (2004; Reprint Sep 2011) Standard for Service-Entrance Cables

1.2 DEFINITIONS

Unless otherwise specified or indicated, electrical and electronics terms used in these specifications, and on the drawings, shall be as defined in IEEE 100.

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.

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

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NOTE: If submittal review by NAVFAC LANT is specifically desired, the responsible Field Engineering Command shall coordinate with Code CIEE during the design process. Include bracketed option and add appropriate information in Section 01 33 00 "SUBMITTAL PROCEDURES" to coordinate with the special requirements.

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Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are [for Contractor Quality Control approval.][for information only. When used, a designation following the

"G" designation identifies the office that will review the submittal for the Government.] [Code CIEE, NAVFAC LANT, will review and approve [all][the "Field Quality Control"] submittals requiring Government approval.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Rectifier installation

Anode installation

Wiring and schematic diagram

Anode junction boxes

SD-03 Product Data

[Rectifiers[; G][; G, [_____]]]

[Impressed current anodes[; G][; G, [_____]]]

[Galvanic anodes[; G][; G, [_____]]]

Permanent reference electrodes[; G][; G, [_____]]

Shunt resistors

Include certified test data for the impressed current anodes stating the maximum recommended anode current output density and the rate of gaseous production if any at that current density.

SD-07, Certificates

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

Icing Climate Requirements[; G][; G, [_____]]

Submit certification from the manufacturer indicating conformance with the paragraph entitled "Icing Climate Requirements."

SD-09, Manufacturer's Field Reports

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

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

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

SD-10 Operation and Maintenance Data

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

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

1.4 SERVICES OF CORROSION ENGINEER

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 water [storage tanks] or submerged structures. Submit evidence of the qualifications of corrosion engineer to the Contracting Officer for review and approval.

1.5 QUALITY ASSURANCE

1.5.1 Regulatory Requirements

In each of the publications referred to herein, consider the advisory provisions to be mandatory, as though the word, "shall" had been substituted for "should" wherever it appears. Interpret references in these publications to the "authority having jurisdiction," or words of similar meaning, to mean the Contracting Officer. Equipment, materials, installation, and workmanship shall be in accordance with the mandatory and advisory provisions of NFPA 70 unless more stringent requirements are specified or indicated.

1.5.2 Standard Products

Provide materials and equipment that are products of manufacturers regularly engaged in the production of such products which are of equal material, design and workmanship. Products shall have been in satisfactory commercial or industrial use for 2 years prior to bid opening. The 2-year period shall include applications of equipment and materials under similar circumstances and of similar size. The product shall have been on sale on the commercial market through advertisements, manufacturers' catalogs, or brochures during the 2-year period. Where two or more items of the same class of equipment are required, these items shall be products of a single manufacturer; however, the component parts of the item need not be the products of the same manufacturer unless stated in this section.

1.5.2.1 Alternative Qualifications

Products having less than a 2-year field service record will be acceptable if a certified record of satisfactory field operation for not less than 6000 hours, exclusive of the manufacturers' factory or laboratory tests, is furnished.

1.5.2.2 Material and Equipment Manufacturing Date

Products manufactured more than 3 years prior to date of delivery to site shall not be used, unless specified otherwise.

1.6 WARRANTY

The equipment items shall be supported by service organizations which are reasonably convenient to the equipment installation in order to render satisfactory service to the equipment on a regular and emergency basis during the warranty period of the contract.

1.7 VERIFICATION OF SITE CONDITIONS

Coordinate and properly relate this work to the work of all trades. Verify that the general locations of the structures to receive protection are shown. Visit the premises and become familiar with all details of the work and working conditions, verify existing conditions in the field, determine the exact locations of structures to be protected, and advise the Contracting Officer of any discrepancy before performing any work. Take resistivity measurement of the water and analysis of the water and provide this data with shop drawings of the system for approval.

PART 2 PRODUCTS

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NOTE: Anode materials, as well as all cathodic protection equipment to be installed in the tank, should be chosen such that there is no contamination of potable water. The type of system to be used, either impressed current or galvanic, must be determined. Select the paragraphs entitled "Impressed Current Anodes" or "Galvanic Anodes" below.

****

2.1 [IMPRESSED CURRENT ANODES

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NOTE: Choose from anodes listed below. The chemical composition listed are examples only. The actual compositions required shall be determined to provide adequate and economical service, and conform to the standards established by NACE.

****

[2.1.1 High-Silicon Chromium Bearing Cast Iron

****

NOTE: High-silicon cast iron anodes are rugged, long lasting, and commonly used in icing and non-icing climates. They are generally classified as relatively non-sacrificial having a consumption rate between 227 to 454 grams 0.5 to 1.0 pounds per ampere-year in most fresh waters.

****

ASTM A518/A518M. Provide cast iron anodes with the following characteristics:

a. Electrical resistivity: 72 micro-ohm-centimeter at minus 6.6 degrees C 20 degrees F (maximum).

b. Physical properties (nominal):

Tensile strength	103.4 MPa 15,000 psi

Compressive strength	689.4 MPa 100,000 psi
Brinell hardness	520
Density	7.0 grams per cubic centimeter
Melting point	1260 degrees C 2300 degrees F

c. Coefficient of expansion from zero to 100 degrees C 32 to 212 degrees F: 0.0000132 centimeter per degree C 0.00000733 centimeter per degree F.

][2.1.2 Aluminum Anodes

****
NOTE: Aluminum anodes are used in cases where annual or frequent replacement is required due to ice damage, and routine cleaning of the tank makes it possible to remove any expended or broken pieces of anode stock from the tank before they accumulate. Also, see the technical note for "Precious Metal Anodes" regarding alternative anode systems for icing conditions. The designer must consider system maintainability impacts when selecting the anode system.
****

Provide aluminum anodes with composition and size conforming to NACE mandated requirements.

][2.1.3 Precious Metal Anodes

****
NOTE: At installations where icing conditions exist and the scaling index of water is less than 20,000 (i.e., low hardness water), the designer should consider using precious metal anodes, such as platinized niobium, platinized titanium, or mixed metal oxide for cathodic protection systems. The consumption rate of precious metal anodes is less than that of other relatively non-sacrificial anodes. However, precious metal anodes are more vulnerable to damage and loss particularly during cleaning and reconditioning of the tank.

Selection of the configuration should be left to the designer of the system. Long, continuous wire from lengths of precious metal anodes may have an attenuating effect. This can be overcome by using an anode header cable connected to lengths of precious metal anodes at a common junction box. Such precious metal anode assemblies must be assembled with factory sealed and tested electrical connections to the anodes.
****

Provide [precious metal anodes] [_____], [solid] [composite] [wire] [rod] [expanded mesh] [ribbon] in form. Anode core shall be [copper] [niobium] [titanium] with [platinum] [mixed metal oxide] [_____] coating with thickness of [_____] millimeters mils.[Precious metal anode assemblies shall have factory sealed and tested electrical connections to the anodes.] Size and length as indicated.

]]2.2 [GALVANIC ANODES

2.2.1 Magnesium Anodes

[ASTM B843] Chemical composition as mandated by NACE.

Bare anode weight: [4.1] [7.72] [14.53] [_____] kg [9] [17] [32] [_____] pounds [not including core].

]2.3 ANODE LEAD WIRES

****

NOTE: Any pinhole, cut, scratch or other damage to the anode cable exposing bare copper to the electrolyte will result in early failure of the impressed current cathodic protection system. For this reason, special, extra heavy insulation is used on anode cable.

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No. [8] [_____] AWG, stranded copper wire conforming to ASTM B3 and ASTM B8. Provide wires with [2.8 mm110 mils [_____] thick, ASTM D1248, high molecular weight polyethylene (HMWPE) insulation] [a primary insulation of ethylene propylene rubber and an outer jacket of chloro sulphonated polyethylene insulation]. Wires shall be [3050] [6100] [_____] mm [10] [20] [_____] feet in length [of sufficient length to extend to the anode header cable [junction box] without splicing].

2.3.1 Attachment of Anode Lead Wire

Install anode lead wires at factory.

2.3.1.1 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 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 not exceed 0.02 ohms.

2.3.1.2 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 not exceed 0.02 ohms.

2.3.1.3 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 not exceed 0.02 ohms.

2.4 RECTIFIERS

****

NOTE: FOR USE ONLY WITH IMPRESSED CURRENT SYSTEMS. Air-cooled rectifiers will be used for most applications. 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.

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2.4.1 Transformers

UL 506 and NEMA ST 1, as applicable.

2.4.2 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.

2.4.3 Rectifying Elements

Provide silicon diode rectifying elements, connected in such manner as to provide full-wave rectification. [Protect silicon diodes with selenium cells or varistors against overvoltage surges and by current limiting devices against overcurrent surges.]

2.4.4 [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 atmospheres exist. When locating oil immersed rectifiers near buildings, consult with paragraph 6-28.2 of UFC 3-600-01, "Fire Protection Engineering For Facilities", for fire safety requirements.
****

NEMA ICS 6, Type [3][3X][4X][7][_____], suitable for [wall][post][pad] mounting. Enclosure shall include hinged door with [padlock hasp] [key lock, provide [three][_____] keys.][locks 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 must be [painted][hot-dipped galvanized][aluminum][stainless] steel [according to the manufacturer's standards].

]2.4.5 [Oil Immersed Enclosures

Provide enclosures of 11-gage steel or heavier, with an accessible drain plug. Provide a hinged lid with quick release clamps to secure it in a closed position. Clearly mark the oil level. Provide a compressive, oil resistance, positive sealing gasket. Based 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].

]2.4.6 Wiring and Schematic Diagram

Provide a complete wiring and schematic diagram of the power unit showing both the ac and the dc connections to anodes on the inside of the cabinet door. Show and label components.

2.4.7 Overload and Short Circuit Protection

Provide UL 489, single-pole, flush-mounted molded case circuit breaker, [magnetic] [thermal-magnetic] type, in the primary circuit of the rectifier supply transformer.

2.4.8 DC Output Control

Provide adjustable dc output voltage by [transformer taps] [automatic controls].

2.4.8.1 [Transformer Taps

****
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.
****

[Transformer taps, [5] [_____] coarse, [5] [_____] fine.] [Variac.] [_____].

]2.4.8.2 [Automatic Controls

Provide control system capable of maintaining a preselected tank-to-water potential, within plus or minus 0.025 volt regardless of changes in water chemistry, temperature, or water level in the tank. [Provide separate dc output circuits, means of adjustment, reference electrodes, and metering for the tank bowl and riser pipe.] Make provisions for readily changing the range and limits of the operating potential.

]2.4.9 Output Voltage and Current Meters

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

2.4.10 Grounding Provisions

Grounding provisions shall [be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.] [comply with NFPA 70 and UL 467 including a ground terminal in the cabinet.] The grounding conductor from the terminal to the earth grounding system shall be solid or stranded copper not smaller than No. 6 AWG. Provide an earth grounding system consisting of one or more rods. Ground rods shall be [copper-clad steel conforming to UL 467] [zinc-coated steel conforming to IEEE C135.30] [solid stainless steel] not less than [16] [19] mm [5/8] [3/4] inch in diameter by [2.4] [3.1] m [8] [10] feet in length. Drive rods full length into the earth. Sectional type rods may be used.

2.4.11 Resistance to Ground

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

Measure the resistance to ground using the fall-of-potential method described in IEEE 81. The maximum resistance of driven ground shall not exceed 25 ohms under normally dry conditions. If this resistance cannot be obtained with a single rod, [_____] additional rods not less than 1.8 m 6 feet on centers, or if sectional type rods are used, [_____] additional couple sections and drive with the first rod. In high-ground-resistance, use UL listed chemically charged ground rods. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, notify the Contracting Officer immediately. Exothermically weld all connections below grade. Exothermically weld connections above grade or use UL 467 approved connectors.

2.4.12 Fuses

Cartridge-type fuses conforming to NEMA FU 1. Provide suitable fuse holders in each leg of the D.C. circuit.

2.4.13 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.

2.4.14 Efficiency

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

2.4.15 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.

2.5 REFERENCE ELECTRODES

[Zinc][copper-copper sulfate] type provided with micro-pore diffusion window for water contact and water-tight plug. Provide cells with No. [10] [12] [_____] AWG, stranded copper conductor with 2.8 mm 110 mils [_____] thick ASTM D1248, high molecular weight polyethylene (HMWPE) insulation 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 micro-amp load, and an initial accuracy of plus or minus 10 millivolts referenced to a calibrated portable reference electrode.

2.6 SHUNT RESISTORS

[0.01] [_____] ohm, [6] [_____] amp, with an accuracy of plus or minus one percent. [Shunts shall conform to MIL-I-1361 [rating as shown]].

2.7 CONDUIT

[UL 6, rigid galvanized steel.] [Outlet boxes: UL 514A and Fitting: UL 514B, threaded hubs.] [Metallic conduit and fittings to be polyvinyl-chloride coated in accordance with [NEMA RN 1, Type A40] [NEMA TC 2, Type EPC-40-PVC]]. Provide nonmetallic conduit conforming to NEMA TC 2. Provide conduit support in accordance with NFPA 70.

2.8 CABLE OTHER THAN ANODE LEAD WIRES

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NOTE: Any pinhole, cut, scratch or other damage to the anode cable exposing bare copper to the electrolyte will result in early failure of the impressed current cathodic protection system. For this reason, special, extra heavy insulation is used on anode cable.

****

Provide copper wire conforming to ASTM B3 and ASTM B8. Wires terminating in a rectifier, junction box or test station shall have a cable identification tag. Refer to paragraph 2.1.4 [_____] for anode lead wires.

2.8.1 AC Power Supply Wiring

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

2.8.2 Anode Wire

Type CP [ASTM D1248, High Molecular Weight Polyethylene (HMWPE)] [cross linked polyethylene (XLPE)] insulation, stranded copper conductors, gage (AWG) as indicated.

The anode wire material shall sustain current densities of 100 ampere per square meter 10.764 square feet in an oxygen generating electrolyte for 20 years. The manufacturer shall certify that a representative sample taken from the same lot used to construct the anode, has been tested and meets the following criteria:

a. The test cell sustains a current density of 10,000 ampere persquare meter 10.764 square feet in a 15 weight percent sulfuric acid electrolyte at 66 degrees C 150 degrees F without an increase in anode to cathode potential of more than 1 volt.

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

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

2.8.3 Rectifier DC Positive (Anode) Header Cable

Type CP [ASTM D1248, High Molecular Weight Polyethylene (HMWPE)] [cross linked polyethylene (XLPE)] insulation, stranded copper conductors, gage (AWG) as indicated. Refer to paragraph 2.1.4 [_____] for anode lead wires.

2.8.4 Cable 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 5 mm 3/16 inch in size. Provide identifier legend [in accordance with the drawings] [_____].

2.8.5 Wire Connectors

UL 486A-486B.

2.8.6 Insulating Tape

UL 510.

2.8.7 Splices

[Splices are not permitted in submerged sections of anode lead wire or anode header cable.] Provide splices with a compression connector on the conductor, 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.

(1) 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 with a clean burning propane gas torch per manufacturer's instructions.

2.9 ANODE JUNCTION BOXES

2.9.1 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. Provide removable terminal board for easy access to wires. Mount the test station atop 1830 mm 6 foot long polyethylene conduit with anchor.

2.9.2 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]. Provide enclosure constructed of [galvanized steel] [painted steel] [aluminum] [fiberglass] [non-metallic] construction with terminal board and labeled with nameplate. 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].

2.9.3 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. Provide insulated terminal boards with 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. Permanently tag test station terminal connections to identify each termination of conductors (e.g. identify the conductors connected to the protected structure, anodes, and reference electrodes). Permanently identify conductors by means of plastic or metal tags, or plastic sleeves to indicate termination. [Color code each conductor as follows:

Anode lead wire: black
Structure lead wire: white
Reference electrode lead wire: red]

2.10 CLEVIS ASSEMBLIES

Provide clevis assemblies, 6.35 mm 1/4 inch flat steel with a spool opening of 53.975 mm 2 1/8 inch, 114.3 mm 4 1/2 inch long to the centerline of the spindle. Provide porcelain spools, with an outside diameter of 57.15 mm 2 1/4 inch and an overall height of 53.975 mm 2 1/8 inch.

2.11 PIN INSULATORS

Provide pin insulator assemblies, 100 mm 4 inches long overall and 6.35 mm 1/4 inch diameter aluminum bolt 19 mm 3/4 inch long attached to the flat end with a aluminum nut and lock washer. Provide porcelain insulator of non-conducting material with hard glazed finish. Provide insulator with a hole through the bottom no smaller than 13 mm 1/2 inch diameter.

2.12 HANDHOLE ASSEMBLIES

Provide aluminum handhole covers, 175 mm 7 inches in diameter and 1.588 mm 1/16 inch thick and connected to insulating rubber gasket, 175 mm 7 inches in diameter and 3.175 mm 1/8 inch thick. Cut handholes 150 mm 6 inches in diameter. Provide handhole assemblies with 12.7 mm 1/2 inch bolts and 6.35 mm 1/4 inch plate clamping bars.

2.13 EXOTHERMIC WELD KITS

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

2.14 MANUFACTURER'S NAMEPLATE

Each item of equipment shall have a nameplate bearing the manufacturer's name, address, model number, and serial number securely affixed in a conspicuous place; the nameplate of the distributing agent will not be acceptable.

2.15 FIELD FABRICATED NAMEPLATES

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NOTE: Use the following paragraph where nameplates are fabricated to identify specific equipment designated on the drawings.

****

ASTM D709. Provide laminated plastic nameplates for each equipment enclosure, relay, switch, and device; as specified or as indicated on the drawings. Each nameplate inscription shall identify the function and, when applicable, the position. Nameplates shall be melamine plastic, 3 mm 0.125 inch thick, white with [black] [_____] center core. Surface shall be matte finish. Corners shall be square. Accurately align lettering and engrave into the core. Minimum size of nameplates shall be 25 by 65 mm one by 2.5 inches. Lettering shall be a minimum of 6.35 mm 0.25 inch high normal block style.

PART 3 EXECUTION

3.1 INSTALLATION

Electrical installations shall conform to IEEE C2, NFPA 70, and to the requirements specified herein.

3.1.1 Anode Installation

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NOTE: Proprietary systems of anode installations are available for areas where icing is expected. For such areas paragraph entitled "Icing Climates"

below should be included.
****

[IEEE C2] [NFPA 70].

3.1.1.1 [Icing Climate Requirements

Suspend anodes in a manner similar to that in non-icing climates, except provisions shall be made to prevent the anodes and suspending cables from being damaged by freezing or falling ice.

]3.1.1.2 Anode Placement

Arrange anodes in the tank [and riser pipe] as shown in the drawings [so that protection can be provided to surfaces without exceeding potentials [in the vicinity of the anodes] that will be detrimental to coatings]. Suspend anodes from roof [plate] [structure] by means of factory-installed connecting wire designed to support the anodes in air [before submergence] without failure of the electrical wire insulation or the electrical conductors. Prevent contact between anode and tank surfaces such as man-access hatches, ladders, heater pipes, and stay rods.

3.1.1.3 Anode Hangers

Anode hangers shall electrically insulate the anode suspending wire from the tank steel.

3.1.1.4 Handholes

Provide a handhole having a diameter of 150 mm 6 inches in the tank roof for each anode string to permit replacement or inspection of anodes.

3.1.2 Anode Connection

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NOTE: A single split-bolt will work loose when wires it connects are moved. Minimum of two split bolts will prevent this from happening. In water tanks, split bolts are used (above water line only) because working space is limited and 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 swedged sleeve connection produced by such tools is more reliable than split bolts.
****

3.1.2.1 Anode Lead Wires

Electrically connect anodes to the positive D.C. header cable with compression connectors or split bolts, or the header cable may terminate in a junction box for connection with all anodes cables. Use a minimum of two split bolts for each connection if split bolts are used. Mark each of the wires terminating in the junction box.

3.1.2.2 Anode Header Cable

Provide header cable on the [underside of the roof] [wall] with electrically insulating hangers which enter the tank near the roof line from an externally mounted junction box. External wiring shall be in conduit. Mark each of the wires terminating in the junction box.

3.1.2.3 Splices

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NOTE: Splices are not allowed below water level.
****

Locate under-roof electric wire splices above the high water line and seal water-tight using a minimum of two 1/2-lap layers of butyl rubber tape followed by two 1/2-lap layers of plastic tape.

3.1.3 Rectifiers

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NOTE: For impressed current systems only.
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3.1.3.1 Rectifier Installation

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.

3.1.3.2 Wire-To-Tank Connections

Connect the structure wire to the tank [_____] [by use of an 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 manufacturer's instructions. Test the integrity of the weld, prior to coating, by striking with a 908 gram two pound hammer.] [Cover connections and surrounding cleaned surface with an electrically insulating coating compatible with the existing coating.]

3.1.4 Permanent Reference Electrodes

3.1.4.1 Permanent Reference Electrode Calibration

Calibrate permanent reference electrodes against a portable electrode in the presence of the Contracting Officer or his approved representative before installation. Calibrate in a test tank containing water with the same composition as the tank to be protected. Permanent electrode shall measure a reference potential agreeing with that measured by the portable electrode within plus or minus 0.010 volt when the sensing windows of the two electrodes being compared are not more than 2 mm 1/6 inch apart but not touching. Remove permanent reference electrodes not within this potential range from the construction site by the end of the day and replace at the Contractor's expense. The testing provision applies to replacement reference electrodes as well.

3.1.4.2 Installation

Provide permanent reference electrodes at points in the tank [and riser pipe] which monitor minimum and maximum tank[/riser]-to-water potentials[, regulate the automatic control system] [_____], and maintain continuous immersion. Sensing windows of reference electrodes shall be equidistant to and located within 25 mm one inch of the steel tank[/rise pipe] surface and be fixed in position, preventing contact with tank wall or appurtenances.

3.2 BOLTED AND RIVETED TANKS

Ensure electrical continuity of joining components.

3.3 GASEOUS EVOLUTION

Provide for possible evolution of gases from anode reaction and ventilation requirements.

3.4 CRITERIA FOR CATHODIC PROTECTION

Conduct in accordance with [NACE SP0388][and][NACE SP0196].

3.4.1 Minimum

The criterion for cathodic protection shall be a negative potential of at least 0.85 volt as measured between the tank[/riser pipe] and a copper-copper sulfate reference electrode across the tank[/riser pipe] to water interface. Determination of this potential shall be made with the protective current applied to the tank [and riser] 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.

3.4.2 Maximum

The potential between a copper-copper sulfate reference electrode and the tank[/riser pipe] at any point shall not be more negative than a negative 1.1 volt potential taken with the [electrode located within 25 mm one inch of the tank[/riser pipe] surface but not touching it] [protective current interrupted instantaneously or modulated] to minimize the voltage drop effect.

3.5 FIELD QUALITY CONTROL

The Government reserves the right to witness tests. Notify 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. Warranty period field testing by the Contractor.

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

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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.

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3.5.1 Destructive Testing

Perform the tests in the presence of the Contracting Officer. Include the cost of an additional anode with the longest lead wire for the destructive test in his bid. Choose one completed anode of each type with lead wires at random for destructive testing and submit to a static pull test. Conduct a lead wire pull test to confirm the minimum lead wire tensile load capacity indicated in paragraph entitled "Attachment of Anode Lead Wire" and following subparagraphs. [The anode shall also be cut into sections to verify conformance with this specification. Check such items as anode-to-wire connection, complete encapsulation of the wire connector, and wire to anode electrical resistance.] [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. Mark all rejected anodes on the ends with a 6" high "X" using yellow spray paint. Remove all failed anodes from the job site by the end of the day. Replace any rejected anodes at contractor's expense. The destructive testing provision also applies to replacement anodes as well.]

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NOTE: Paragraph entitled "Wire for Power Service" for impressed current systems only.
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[3.5.2 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 megohmmeter having a 500-volt rating.

]3.5.3 Initial Cathodic Protection System Field Testing

Upon completion of the installation, fill tank to maximum working level, and the Contractor's corrosion engineer shall test and inspect the cathodic protection system in the presence of the Contracting Officer or his designated representative. Record test data, including date, time, and location of testing and submit to the Contracting Officer. Contractor shall correct and retest, at his expense, deficiencies in the materials and installation observed during the tests and inspections. Take measurements with voltmeters having input impedance not less than 10 megohms. Testing shall include the following:

a. Base potential tests: At least [one week] [24 hours] [_____] after the tank has been filled, but before energizing of the cathodic protection system, measure the base (native) structure-to-water potentials of the tank [and riser]. The locations of these measurements shall be identical to the locations specified for measuring energized structure-to-water potentials.

b. Permanent reference electrode tests: Verify proper operation and calibration of the reference electrode (s) including the entire reference electrode wiring circuit. Verify calibration of the reference electrode in accordance with the paragraph entitled "Permanent Reference Electrode Calibration". [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.] Remove permanent reference electrodes not within these potential differences from the construction site by the end of the day and replace at the contractor's expense. The testing provision also applies to replacement reference electrodes as well.

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NOTE: For impressed current systems only.
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[c. Rectifier testing: Upon completion of the installation, "Base Potential" tests, and "Permanent Reference Electrode" tests, energize and adjust the rectifier to provide current to the anode at a level that will protect the tank[/riser pipe] in accordance with the NACE criteria listed in this specification. Measure dc output of the rectifier and current output of each anode at different rectifier settings. Measure the current outputs across the installed shunts. Verify these readings using portable, calibrated meters and shunts. Testing shall demonstrate if the rectifier system is capable of functioning properly as required to provide effective cathodic protection.]

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NOTE: For galvanic systems only.
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[d. Anode-to-water potential and anode output current tests: Upon completion of the installation, "Base Potential" tests, and "Permanent Reference Electrode" tests, measure anode-to-water potential of each anode or each anode string with the anodes disconnected. After connecting the anodes to the tank [through junction box], measure current output of each anode or anode string across the calibrated shunt.]

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NOTE: For all types of cathodic protection systems.
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e. Energized tank[/riser pipe]-to-water potential tests: After operation of the cathodic protection system for at least 24 hours [one week] [_____], perform the tank[/riser pipe]-to-water measurements listed in the following five paragraphs with a portable reference electrode placed within 25 mm one inch of, but not touching, the tank[/riser pipe] wall and bottom surfaces and appurtenances.

(1) On a vertical line midway between two anode strings beginning at a point 305 mm one foot below water level and continuing at point 915 mm 3 feet apart until the bottom of the tank is reached.

(2) On a second vertical line midway between two anode strings on the opposite side of the tank from the first vertical line beginning at a point 305 mm one foot below water level and continuing at points 915 mm 3 feet apart until the bottom of the tank is reached.

(3) Across the bottom of the tank in a line between the two vertical lines at [915] [_____] mm [3] [_____] foot intervals.

(4) In at least [4] [_____] places which are close to anodes.

(5) On a vertical line in the riser pipe beginning at the top of the

riser and continuing at [915] [_____] mm [3] [_____] foot intervals until the bottom of the riser is reached.

3.5.4 Initial Cathodic Protection System Field Test Report

Submit a field test report of the cathodic protection system. Record on applicable forms all rectifier measurements, anode output current measurements, and structure-to-electrolyte measurements, including initial potentials. Coordinate identification of rectifiers, anode junction boxes, test locations, and test stations with the as-built drawings and provide on system drawings in the report. Locate, correct, and report to the Contracting Officer any short circuits encountered during the checkout of the installed cathodic protection system.

3.5.5 One Year Warranty Period Testing

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. Commence the performance period for these tests 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. The One Year Warranty Period Cathodic Protection System Field Test Report, including field data, shall be certified by the Contractor's corrosion engineer.

3.5.6 Final Field Testing

Conduct final field testing of the cathodic protection system utilizing the same procedures specified under, "Initial Cathodic Protection System Field Testing". Inspect, test, and adjust the cathodic protection system after one year of operation to ensure its continued conformance with the criteria outlined below. Commence the performance period for these tests 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. The Final Cathodic Protection System Field Test Report shall be certified by the Contractor's corrosion engineer and included as an attachment to the operation and maintenance manual in accordance with Section 01 78 23 OPERATION AND MAINTENANCE DATA.

3.6 DEMONSTRATION

3.6.1 Instruction to Government Personnel

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NOTE: There are restrictions on the type and extent of training. Training is usually on-site, 2 days or less. 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.

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Furnish the services of competent instructors to give full instruction to designated Government personnel in the adjustment, operation, and maintenance of the specified systems and equipment, including pertinent safety requirements as required. Instructors shall be thoroughly familiar with all parts of the installation and shall be trained in operating theory as well as practical operation and maintenance work. Instruction shall be given during the first regular work week after the equipment or system has been accepted and turned over to the Government for regular operation. Provide [8] [_____] hours of instruction for [_____] personnel.

-- End of Section --