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Change 1 - 05/13

Preparing Activity: USACE **Superseding**
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UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2021
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DIVISION 26 - ELECTRICAL

SECTION 26 42 15.00 10

CATHODIC PROTECTION SYSTEM (STEEL WATER TANKS)

02/13, CHG 1: 05/13

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SECTION 26 42 15.00 10

CATHODIC PROTECTION SYSTEM (STEEL WATER TANKS)
02/13, CHG 1: 05/13

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

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

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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 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.

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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.

AMERICAN WATER WORKS ASSOCIATION (AWWA)

AWWA D104	(2011) Automatically Controlled, Impressed-Current Cathodic Protection for the Interior Submerged Surfaces of Steel Water Storage Tanks

ASTM INTERNATIONAL (ASTM)

ASTM D1248	(2016) Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

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

NACE INTERNATIONAL (NACE)

NACE SP0388	(2018) Impressed Current Cathodic Protection of Internal Submerged Surfaces of Carbon Steel Water Storage Tanks - Item No. 21040

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA TC 2	(2020) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2020; ERTA 20-1 2020; ERTA 20-2 2020; TIA 20-1; TIA 20-2; TIA 20-3; TIA 20-4) National Electrical Code

UNDERWRITERS LABORATORIES (UL)

UL 6	(2007; Reprint Sep 2019) UL Standard for Safety Electrical Rigid Metal Conduit-Steel

UL 467	(2013; Reprint Jun 2017) UL Standard for Safety Grounding and Bonding Equipment
UL 506	(2017) UL Standard for Safety Specialty Transformers
UL 510	(2020) UL Standard for Safety Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514A	(2013; Reprint Aug 2017) UL Standard for Safety Metallic Outlet Boxes

1.2 SUBMITTALS

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NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified 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 Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters 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" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

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" or "S" classification. Submittals not having a "G" or "S" classification are [for Contractor Quality Control approval.][for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government.] Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-02 Shop Drawings

Detail Drawings; G[, [_____]]

Submit all detail drawings at one time, as a single submittal, in order to demonstrate that the items have been properly coordinated and will function properly as a unit. Make a notation on each shop drawing submitted as to the item's specific use, either by a particular type number referenced on the drawings or in the specifications, or by a description of its specific location.

SD-03 Product Data

Miscellaneous Materials; G[, [_____]]
Equipment; G[, [_____]]
Spare Parts
Remote Monitoring Equipment; G[, [_____]]

SD-05 Design Data

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

SD-06 Test Reports

Anode Connecting Cables
Testing, Adjusting, and Placing in Service

SD-07 Certificates

Services of "Corrosion Expert"; G[, [_____]]
Remote Monitoring Equipment
Anode Installation

SD-10 Operation and Maintenance Data

Cathodic Protection System; G[, [_____]]

[Six][_____] copies

Training; G[, [_____]]

1.3 QUALITY ASSURANCE

1.3.1 Services of "Corrosion Expert"

Obtain the services of a "corrosion expert" to supervise and inspect the installation and performance of the cathodic protection system. "Corrosion expert" refers to a person, who, by reason of thorough knowledge of the physical sciences and the principles of engineering and mathematics acquired by professional education and related practical experience, is qualified to engage in the practice of corrosion control on steel water tanks.

a. Such a person must be accredited or certified by NACE International, The Corrosion Society, (NACE) as a NACE certified Corrosion Specialist or a NACE certified Cathodic Protection (CP) Specialist or be a registered professional engineer who has certification or licensing

that includes education and experience in corrosion control on steel water tanks, if such certification or licensing includes 5 years experience in corrosion control on steel water tanks of the type under this contract.

b. The "corrosion expert" shall ensure that the cathodic protection system is installed, tested, and placed into service in accordance with the requirements specified; and shall also design, make calculations, and assure quality control as required.

c. Submit evidence of qualifications of the "corrosion expert". Name and qualifications shall be certified in writing to the Contracting Officer's Representative prior to the start of construction. Submit the certification giving the name of the firm, the number of years of experience, and a list of not less than five of the firm's installations three or more years old that have been tested and found satisfactory.

1.3.2 Detail Drawings

Submit [6] [_____] copies of detail drawings, within 45 days after the date of award of the contract, before commencement of any work and in accordance with SPECIAL CLAUSES, consisting of a complete list of equipment and materials including manufacturer's descriptive and technical literature, catalog cuts, and installation instructions. Provide on the drawings tank dimensions, anode arrangement for both elevated and sectional views of the tank, anode size and number, anode material, anode-suspension details, conduit size, wire size, rectifier size and location, handhole details, wiring diagram, and any other pertinent information considered necessary for the proper installation and performance of the system. Shop drawings shall also contain complete wiring and schematic diagrams and any other details required to demonstrate that the system has been coordinated and will function as a unit. The list of materials and equipment shall include catalog cuts, diagrams, and other descriptive data required by the Contracting Officer for the following list of material. Partial lists submitted from time to time will not be allowed.

a. Water resistivity and water analysis.

b. Conductors.

c. Anodes and anode mounting details.

d. Coating material in areas where welding and other work is accomplished.

e. Insulated resistance wire.

f. Layout of anodes in tanks, test stations and isolation points, and grounding.

g. Special details.

h. Certified experience data of installing firm.

i. Exothermic weld equipment and material; bonding requirements and details.

j. Test [station][and][cabinet].

k. Welding method for electrical connections and steel ring connections.

l. Calculations for:

(1) Total current required for system

(2) Life of the anodes

(3) Anode geometry (showing areas of coverage)

1.4 EXTRA MATERIALS

Submit spare parts data for each different item of material and equipment specified, after approval of the detail drawings and not later than [_____] months prior to the date of beneficial occupancy. The data shall include a complete list of parts, special tools, and supplies with current unit prices and source of supply. One spare anode of each type shall be furnished

PART 2 PRODUCTS

2.1 SYSTEM DESCRIPTION

Provide and install a complete [automatic] [manual] [_____] cathodic protection system, to prevent corrosion on the interior submerged surfaces of the water tank, and all equipment, wiring, and wiring devices, necessary to produce a continuous flow of direct current from annodess in the electrolyte to the metal tank surfaces. Submit, within [30] [45] [_____] days after receipt of notice to proceed, an itemized list of equipment and materials including item number, quantity, and manufacturer of each item. The list shall be accompanied by a description of procedures for each type of testing and adjustment, including testing of coating for thickness and holidays. Also, submit proof that the materials and equipment furnished under this section conform to the specified requirements contained in the referenced standards or publications. The label or listing by the specified agency is acceptable evidence of such compliance. Do not commence installation of materials and equipment until these submittals are approved. The installation shall meet the criteria and protection outlined in paragraph CRITERIA OF PROTECTION for a 20 year life. Place the cathodic protection system in operable status.

a. The purpose of the system is to adequately and efficiently protect the surfaces of the metal against corrosion where the surfaces are in contact with water; this is in addition to the protective coating on the tank. The contract drawings indicate the location and size of the tank. The design of this system is based on an impressed current system.

b. Use this impressed current system, as described, with anodes as found necessary in calculations and submitted data to meet this specification. Install anodes in sufficient number and of the required type, size and spacing to obtain a uniform current distribution of 3.5 milliamperes per 0.09 square meters 1 square foot to all submerged surfaces in the tank when filled with water to the over-flow level. Suspend the anodes as approved by the Contracting Officer's Representative, which also shall be in accordance with the methods allowed and specified in this specification. If the anodes are suspended from the tank roof, suspend the anodes from the roof

steel with hangers or supporting cables that are electrically isolated from both the metal roof and the water electrolyte. Additionally, locate and install anodes suspended from the tank roof so that the roof door is midway between two adjacent anodes. Hang all anodes, regardless of the suspension method utilized, clear of contact with such items as ladders, heater pipes, and stay rods.

c. Contractor's Modifications. The cathodic protection system may be modified after review of the project, site verification and analysis if the proposed modifications include impressed current anodes and rectifiers and will provide equal or better overall system performance. Submit [6] [_____] copies of detail drawings, showing proposed changes in location and scope or performance, indicating any variations from, additions to, or clarifications of contract drawings. The drawings shall show proposed changes in anode arrangement, anode size and number, anode materials and layout details, conduit size, wire size, mounting details, wiring diagram, method for electrically isolating where and as necessary, and any other pertinent information to the proper installation and performance of the system. This modification shall be fully described and submitted for approval to the Contracting Officer's Representative. Modifications or additional anodes shall be at no additional cost to the Government and incorporate all requirements of this specification.

d. The proposed system shall achieve a minimum "Instant Off" potential of minus 850 millivolts with reference to a saturated copper-copper sulfate reference cell on the tank components. Take measurements and adjust the current and voltage of the rectifier as required to produce the required "Instant Off" potential between the structure being tested and the reference cell. Obtain this potential over 95 percent of the metallic area without the "Instant Off" potential exceeding 1100 millivolts.

e. All interior submerged metallic surfaces and components of the water storage tank shall be electrically continuous or made by the contractor to be electrically continuous by welding, installation of bonding conductors, or in some other acceptable manner as submitted to and approved by the Contracting Officer's Representative. If any water storage tank provided and installed under this contract is not of welded steel construction but is of construction where the interior submerged steel surfaces are not inherently electrically continuous, such as with bolted steel panel constructed tanks, then it shall be the full responsibility of the contractor to ensure that all interior submerged metallic surfaces and components of the water tank are made electrically continuous and that the cathodic protection system specified herein is provided and installed in order to perform as specified. All panels of bolted steel tanks shall be bonded together in such a fashion as to ensure that all interior submerged surfaces of the tank are electrically continuous.

2.2 IMPRESSED CURRENT ANODES

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NOTE: Only impressed current anodes selected from the types included in this specification shall be utilized; the application of galvanic type anodes for water storage tanks is not covered by this specification. Seasonal or temporary type impressed current anodes, such as aluminum, are not normally

desirable in military projects and, consequently, are not included herein. Long-life anode systems, such as those specified in this specification, are defined, and additional selection criterion are provided, in the NACE and AWWA standards referenced herein.

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[2.2.1 High Silicon Cast Iron Anodes

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NOTE: High silicon cast iron anodes are rugged, long lasting, and commonly used in icing and non-icing climates. The anodes are less vulnerable to damage and loss than other anodes where ice is heavy and the tank level fluctuates over a wide range. They are generally classified as relatively non-sacrificial having a consumption rate between 0.2 to 0.5 kg per ampere year 0.5 to 1.0 pounds per ampere year in most fresh waters.

Although high silicon cast iron anodes are resistant to damage from ice, experience has indicated that their cabling and suspension system is vulnerable to damage from ice when installed inside tanks subject to periodic ice formation. In climates subject to icing, if it is not feasible or possible, during freezing temperatures, to operate the tank in a manner to prevent ice accumulation on the anodes and/or their suspension system, then an impressed current anode installation should be specified that is unaffected by ice accumulation within the tank, as is suggested by NACE SP0388. In tanks subject to ice formation and accumulation, a precious metal type anode system, utilizing a suitable suspension system as specified by this section, should be considered for installation.

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

2.2.1.1 Chemical Composition (Nominal)

Element	Percent by Weight
Silicon	14.20 - 14.75
Manganese	1.50 maximum
Carbon	0.75 - 1.15
Chromium	3.25 - 5.00
Iron	Balance

2.2.1.2 Electrical Resistivity

Electrical Resistivity shall be 72 microhm-centimeter at minus 7 degrees C 20 degrees F (maximum).

2.2.1.3 Physical Properties (Nominal)

Tensile strength	103.4 MPa15,000 psi
Compressive strength	689.5 MPa100,000 psi
Brinell hardness	520
Density	7.0 grams per cubic centimeter
Melting point	1260 degrees C2300 degrees F
Coefficient of expansion from 0 to 100 degrees C 32 to 212 degrees F	132 nanometer per degree C 0.00000733 centimeter per degree F

2.2.1.4 Anode Connecting Cables

Anodes shall have connecting cables installed at the factory. Submit a certified test report showing that the connecting method has passed a 120-day laboratory test without failure at the place of connection wherein the anode was subjected to maximum recommended current output while immersed in a 3 percent sodium chloride solution.

][2.2.2 Precious Metal Anodes

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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. When used in tanks subject to icing conditions, anode suspension shall conform to this specification section and AWWA D104.

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.

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[2.2.2.1 Mixed Metal Oxide (MMO) Coated

The electrically conductive coating shall contain a mixture consisting of iridium, tantalum, and titanium oxides. The average composition shall be composed of a 50/50 atomic percent mixture of iridium and titanium oxides with an acceptable amount of tantalum. The anode must be inert and the electrically conductive mixed metal oxide coating dimensionally stable. The mixed metal oxide coating shall be applied to the wire anode by a manufacturer that has a minimum 5 years experience in manufacturing and applying mixed metal oxide coating to titanium anode substrates. Sinter the mixed metal oxide to the titanium surface to remain tightly bound to the surface when considerable mechanical stresses are applied to the anode surface. The anodes shall have connecting cables installed at the factory. Make the connection between the anode and lead wire with a solid crimp coupling, or with solder. Seal the connection in cast epoxy.

][2.2.2.2 Platinum Plated

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

]2.2.2.3 Anode Life Test

The anode wire material shall sustain current densities of 100 ampere per square meter 10.764 square feet in an oxygen generating electrolyte for a 20 year period. The manufacturer shall certify that a representative sample tested by an independent laboratory meets this criterion.

]2.3 RECTIFIERS AND ASSOCIATED EQUIPMENT

2.3.1 Rectifier Unit

****

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

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Rectifier unit shall consist of a transformer, rectifying elements, [transformer tap adjuster,] terminal block, [one dc output voltmeter, one dc output ammeter,] [one combination volt-ammeter,] one toggle switch for each meter, appropriate circuit breakers or fuse holders with fuses for each dc circuit, variable resistors, an ac power-supply circuit breaker, lightning arresters for both input and output; all wired and assembled in a weatherproof cabinet. The overall efficiency of the rectifier shall be not less than 65 percent when operated at nameplate rating and shall be capable of supplying continuous full rated output at an ambient temperature of 44 degrees C 112 degrees F in full sunlight with expected life in excess of 10 years.

2.3.1.1 Transformer

Transformer shall conform to UL 506.

2.3.1.2 Rectifying Elements

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NOTE: Below about 500 volt-amperes of dc rated output, single phase selenium rectifiers cost less to acquire and operate than silicon rectifiers. Above 1000 volt-amperes silicon rectifiers are more economical for both single phase and three phase. Silicon rectifiers are more economical to repair.
****

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

2.3.1.3 Meters

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

2.3.1.4 Circuit Breaker(s)

Install a [single] [double] [three]-pole, flush-mounted, fully magnetic, properly rated nonterminal type circuit breaker in the primary circuit of the rectifier supply transformer.[Install a single-pole, flush-mounted, properly rated nonterminal type circuit breaker in each dc circuit output of the rectifier.]

2.3.1.5 Fuses

In the event that fuses and fuse holders rather than circuit breakers are used, provide cartridge-type fuses conforming to NEMA FU 1 with suitable fuse holders in each leg of the dc circuit.

2.3.1.6 Automatic Cathodic Protection Control

Provide a system capable of maintaining a tank-to-water potential criterion of protection within plus or minus 25 millivolts regardless of changes in water chemistry, temperature, or water level in the tank. Provision shall be made for readily changing the range and limits of the criterion. The controller shall be either housed integrally with the rectifier or in a separate weatherproof cabinet with provisions for locking. The automatic controller shall be a completely solid-state design, and shall be capable of automatically maintaining the tank-to-water potential at minus 900 millivolts with respect to a copper-copper sulfate reference electrode within an accuracy of 25 millivolts. The tank-to-water potential measured and maintained by the controller shall be free of "IR" drop error.

2.3.1.7 Tank To Water Potential Meter

The controller shall be equipped with a calibrated voltmeter having an internal impedance exceeding 1 megohm which shall be so connected to read, from the system reference cell, the tank-to-water potential being maintained by the cathodic protection system. This voltage reading shall be free of "IR" drop error.

2.3.2 Cabinet

Construct cabinet of [not lighter than 1.56 mm16 gauge [steel] [hot dipped galvanized steel] [stainless steel] [aluminum]] [molded fiberglass reinforced polyester], and provided with a full door. The enclosure shall have oil-resistant gasket. The door shall be hinged and have a hasp that will permit the use of a padlock. The cabinet shall be fitted with screened openings of the proper size to provide for adequate cooling. Holes, conduit knockouts, or threaded hubs of sufficient size and number shall be conveniently located.

2.3.2.1 Wiring Diagram

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

2.3.2.2 Grounding

Grounding provisions shall [be as specified in Section 26 20 00 INTERIOR DISTRIBUTION SYSTEM.] [comply with NFPA 70 and UL 467 including a ground terminal in the cabinet.] The grounding conductor from the terminal to the earth grounding system shall be solid or stranded copper not smaller than No. 6 AWG. The earth grounding system shall consist of one or more 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. Rods shall be driven full length into the earth. Sectional type rods may be used.

2.3.2.3 Resistance to Ground

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NOTE: Remove this pagagraph if not required in the project
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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 sections may be coupled and driven with the first rod. In high-ground-resistance, UL listed chemically charged ground rods may be used. If the resultant resistance exceeds 25 ohms measured not less than 48 hours after rainfall, immediately notify the Contracting Officer's Representative. Fusion weld connections below grade. Fusion weld connections above grade or use UL 467 approved connectors.

2.3.2.4 Cabinet Paint System

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

2.3.3 Wiring

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

2.3.4 Oil Immersed Enclosures

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NOTE: The enclosure should not be used in areas prone to flooding unless required for hazardous locations. Provisions should be made for flooding.

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

[2.3.5 Remote Monitoring Equipment

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NOTE: Remote monitoring of the cathodic protection system may be considered in remote and difficult to reach locations. In such locations, remote monitoring equipment can aid in data collection, reduce monitoring costs, and provide data more frequently and over a variety of tank operations. In these cases, the designer may select one of the remote monitoring systems provided under this paragraph. A SCADA-based system should be selected only where an existing operable SCADA system is available; additional SCADA systems should not be installed. For locations where existing SCADA systems are not readily available or for very remote areas, a cell phone-based system or satellite down linked data system may be more feasible. The choice of whether to select a drive-by system or a cell phone-based system depends on the reliability of the

cell phone signal at the particular project location. Regardless of the system selected, the designer must carefully coordinate with designated Installation operation and maintenance personnel in order to interface with the existing SCADA system or to provide another viable remote monitoring system suitable for the particular maintenance program.
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Provide a complete and operable [SCADA-based] [drive-by] [cell phone-based] [satellite down linked data] type remote monitoring system which is fully compatible, operable, and integratable with the tank cathodic protection system and, if existing, the installation-wide cathodic protection systems' remote monitoring system. All cathodic protection system remote monitoring equipment, wiring, and wiring devices necessary to accurately monitor the cathodic protection system rectifier output voltage, rectifier output amperage, and permanent reference electrode potentials shall be provided in order to have the capability of monitoring from a location remote to the tank as designated by the Contracting Officer's Representative. Provide all remote monitoring unit (RMU) transmitting equipment; system receiving equipment; other equipment and devices, including suitable laptop computers as necessary to complete the system; wiring; wiring devices; software; and all other items necessary to meet the requirements specified herein. House the RMU either integrally with the rectifier or in a separate weatherproof cabinet which meets the specifications of this section and has provisions for locking.[SCADA-based type remote monitoring systems shall be completely coordinated, compatible, and integrated with the existing installation-wide SCADA system. All SCADA system wiring, wiring devices, and other associated equipment shall be provided and installed as specified in [Section 27 10 00 BUILDING TELECOMMUNICATIONS CABLING SYSTEM][and][Section 33 82 00 TELECOMMUNICATIONS OUTSIDE PLANT].] The RMU and associated receiving devices shall be of completely solid-state design. Place the remote monitoring system in operable status. The system provided shall meet the following functional requirements:

a. The water tank cathodic protection system's remote monitoring interrogation/transmission unit shall be capable of delivering system DC voltage, amperage, and instant-off (i.e., free of "IR" drop error) potential measurements and shall come complete with all related software for collection of the data for use in an Excel Spreadsheet format. The Remote Monitoring System shall be capable of monitoring and delivering the potential measurements of all permanent reference electrodes required by this specification and shall identify all reference electrodes that are currently being utilized for automatic control of the rectifier.

b. All data provided by the remote monitoring equipment shall be within 2 percent of the same measurements taken locally at the tank site when utilizing the rectifier ammeter, rectifier voltmeter, and the tank to water potential meter, all of which are specified elsewhere in this specification section. The "Corrosion Expert" shall verify, in the presence of the Contracting Officer's Representative, the accuracy of the values provided by the remote monitoring system as compared to the same readings provided locally at the tank.

]2.4 MISCELLANEOUS MATERIALS

2.4.1 Reference Electrodes

The electrodes shall be copper-copper sulphate type provided with micro-pore diffusion window for water contact and water-tight plug for renewal of copper sulphate crystals and solution. A minimum of four reference electrodes shall be part of this system. Electrodes shall be designed for 15 year life.

2.4.2 Electrical Wire and Associated Materials

2.4.2.1 Anode Connecting Wire

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

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

2.4.2.2 Anode Header Cable

Cable for anode header and distribution shall be [_____] AWG stranded copper wire with type CP high molecular weight polyethylene, 2.8 mm 7/64 inch thick insulation, 600-volt rating. Cable-to-anode contact resistance shall be 0.003 ohms maximum.

2.4.2.3 Reference Electrode Wire

Reference electrode wire shall be stranded copper wire with NFPA 70 type RHW-USE or polyethylene insulation.

2.4.3 Conduit

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

2.4.4 Test Boxes and Junction Boxes

Boxes shall be outdoor type conforming to UL 514A.

2.4.5 Polyethylene Insulation

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

2.4.5.1 High Molecular Weight Polyethylene

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

2.4.5.2 High Density Polyethylene

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

2.4.6 Pressure-Sensitive Vinyl Tape

Tape shall conform to UL 510.

PART 3 EXECUTION

3.1 EXAMINATION

Coordinate and properly relate this work to the work of all trades. The general locations of the structures to receive protection are shown. Visit the premises and after becoming 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 detail drawings of the system for approval.

3.2 CRITERIA OF PROTECTION

Acceptance criteria for determining the adequacy of protection on the internal submerged surfaces of steel water tanks shall be in accordance with NACE SP0388 and as specified below.

3.2.1 Minimum

The criterion of protection is a negative voltage of at least minus 850 millivolts as measured between the tank and a saturated copper-copper-sulphate reference electrode. Determination of this voltage shall be made with the cathodic protection system in operation and after the system has been in operation for a minimum period of 72 hours. Voltage drops shall be considered for valid interpretation of this voltage measurement. A minimum of minus 850 millivolts "instant off" potential between the tank surface being tested and the reference electrode shall be achieved over 95 percent of the area of the structure. Obtain adequate number of measurements over the entire tank surface to verify and record achievement of minus 850 millivolts "instant off". This potential shall be obtained over 95 percent of the total metallic area without the "instant off" potential exceeding the maximum limit indicated below.

3.2.2 Maximum

In order to mitigate disbonding of the interior coating in the tank, potential between a copper-copper-sulphate reference electrode and the tank at any point shall not be more negative than minus 1.1 volt measured with the electrode located between 6 mm 1/4 inch and 13 mm 1/2 inch away from the steel surface but not touching it.

3.3 ANODES

3.3.1 Anode Installation

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NOTE: In water tanks, split bolts are used (above the waterline only) because working space is limited and hydraulic or mechanical compression tools may be cumbersome and hazardous to use; since a single split-bolt will work loose when the wires it connects are moved, a minimum of two split bolts should be used. At ground level or in trenches, compression tools can be used conveniently, and the swaged sleeve connection produced by such tools is more reliable than split bolts.

For tanks subject to ice formation, select the bracketed text (below) beginning with "For tank interiors subject to icing," otherwise, select the first bracketed text in this paragraph.

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[For tank interiors not subject to icing, install anodes in accordance with NACE SP0388, AWWA D104, this specification, and the indicated details. Suspend anodes from roof [plate] [structural members] 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 conductor. Suspend anodes in a manner preventing contact with tank surfaces and hang clear of man-access roof hatches and such items as ladders, heater pipes, and stay rods. Anode hangers shall electrically insulate the anode suspending wire from the tank steel. Provide a handhole having a minimum diameter of 150 mm 6 inches in the tank roof for each anode to permit replacement or inspection of anodes. Certify that the method chosen has been used successfully for similar applications.][For tank interiors subject to icing, install anodes in accordance with AWWA D104, this specification, and the indicated details. Install anodes in a manner preventing contact with tank surfaces and clear of such items as ladders, heater pipes, and stay rods. Certify that the method chosen has been used successfully for similar applications.]

3.3.2 Anode Connections

Where this specification allows the use of header cables, anodes shall be electrically connected to the positive dc header cable with compression connectors or split bolts, or the header cable may terminate in a junction box for connection with all anode cables. Use a minimum of two split bolts for each connection if split bolts are used. Where practical, such as within tanks not subject to ice formation, install header cable on the underside of the roof with electrically insulating hangers and enter the tank near the roof line from an externally mounted junction box. External wiring shall be in conduit. Make all under-roof electric wire splices above the high water line and sealed 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.

3.4 RECTIFIERS

3.4.1 Rectifier and Control/Monitoring Installation

Mounting shall be [of the wall mounted type.] [of the cross-arm mounted type.] [of the floor mounted on stand type.] [as shown.]

3.4.2 Rectifier Grounding

The grounding system for grounding rectifier cabinets shall have a resistance to earth of not more than 25 ohms as determined by an approved method.

3.5 PERMANENT REFERENCE ELECTRODES

3.5.1 Calibration

Calibrate permanent reference electrodes against a standard electrode before installation. Perform calibration in a test tank containing water with the same composition as the tank to be protected. The permanent electrodes shall measure reference voltage agreeing with that measured by the standard electrode within plus or minus 0.005 volt when the sensing windows of the two electrodes being compared are not more than 4 mm 1/6 inch apart but not touching.

3.5.2 Installation

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NOTE: The requirements for installation of permanent reference electrods are similar to those for anode installation. See the NOTE in paragraph Anode Installation.

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Reference electrodes shall be operable under the same icing conditions as the anode system. Installation of permanent reference electrodes shall be made at points in the tank which will monitor minimum and maximum tank-to-water potentials [and as otherwise needed for automatic control system]. Sensing windows of reference electrodes shall be located between 6 mm 1/4 inch and 13 mm 1/2 inch away from the steel surface sensed and shall be fixed in position preventing contact with tank steel.

3.6 TESTING, ADJUSTING, AND PLACING IN SERVICE

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

If the cathodic protection system has been modified from the original design, include the Contractor's Modifications shall in the test reports. Submit final report including measurements throughout the tank area, indicating that the addition of any anodes (if it became necessary to add anodes as a result of modifications submitted to and approved by the

Contracting Officer) corrected the conditions which made the additional anodes necessary. The following are required: Installation and testing procedures, anode number, life, and parameters to achieve protective potential.

3.6.1 Electrode Baseline, Instant-Off, and ON Potential Measurements

Upon completion of the installation, fill the tank to maximum working level, and obtain baseline, instant-off, and ON potential measurements as described herein. Obtain baseline potential measurements prior to energizing the cathodic protection system; obtain instant-off and ON potential measurements with the entire cathodic protection system in operation and after it has been in operation for a minimum of 72 hours. Make electrode baseline, instant-off, and ON potential measurements using a copper-copper sulphate reference electrode and a potentiometer-voltmeter, or a direct current voltmeter having an input impedance of not less than 10 megohms per volt and a full scale of 10 volts. Locate these measurements as described in this specification; take baseline, instant-off, and ON potential measurements at each described location. Record the values obtained and the date, time, and locations of measurements.

3.6.1.1 Tank-to-Water Potential Measurements

The following series of tank-to-water potential measurements with a portable reference electrode placed not more than 13 mm 1/2 inch away from but not touching the tank wall shall be performed:

a. On a vertical line midway between two anode strings beginning at a point 300 mm 1 foot below water level and continuing at points 900 mm 3 feet apart until the bottom of the tank is reached. If anodes are attached to floatation assemblies rather than on strings hanging from the tank roof, locate the vertical line of measurements as far as possible from any anode material.

b. 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 300 mm 1 foot below water level and continuing at points 900 mm 3 feet apart until the bottom of the tank is reached. If anodes are attached to floatation assemblies rather than on strings hanging from the tank roof, locate the vertical line of measurements as far as possible from any anode material.

c. Across the bottom of the tank in a line between the two vertical lines at 900 mm 3 foot intervals.

d. In at least four places which are closest to anodes.

3.6.1.2 Reference Electrode Calibration

The portable reference electrode used for the test shall be calibrated against the standard electrode specified in paragraph PERMANENT REFERENCE ELECTRODES.

3.6.1.3 Test Measurement Recording

All test measurements and their locations, as well as measurements made with the permanent electrodes simultaneously with the test measurements, shall be recorded.

3.6.2 Adjusting

Final adjustment of the rectifier output current shall be made so that repeated voltage readings taken as specified for testing meet the criteria in paragraph CRITERIA OF PROTECTION.

3.7 Cathodic Protection System Operation and Maintenance Manuals

Operating manual outlining the step-by-step procedures required for system startup, operation, adjustment of current flow, and shutdown shall be provided. The manuals shall include the manufacturer's name, model number, service manual, parts list, and brief description of all equipment, including any remote monitoring equipment, and their basic operating features.

Maintenance manual listing routine maintenance procedures, recommendation for maintenance testing, possible breakdowns and repairs, and troubleshooting guides shall be provided. Include single line diagrams for the system as installed, instructions in making tank-to-reference electrode potential measurements for both permanent and portable electrodes, and describe the frequency of monitoring. If remote monitoring equipment was installed under this contract, then the maintenance manual shall also include maintenance instructions on this equipment to the extent required by this paragraph. The instructions shall include precautions to ensure safe conditions during repair of system.

3.8 TRAINING

Conduct a training course for the operating staff as designated by the Contracting Officer's Representative. The training period shall consist of a total of [_____] hours of normal working time and start after the system is functionally complete but prior to final acceptance tests. Submit the proposed Training Course Curriculum (including topics and dates of discussion) indicating that all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations, including testing procedures included in the maintenance instructions, are to be covered. The field instructions shall cover all of the items contained in the operating and maintenance instructions, as well as demonstrations of routine maintenance operations. Notify the Contracting Officer's Representative at least 14 days prior to date of proposed starting of the training course.

3.9 PLACING IN SERVICE

After final adjustment, place the cathodic protection system in service and record the condition of the system as left by the Contractor indicating transformer tap settings; voltage readings from reference electrode to tank, readings both horizontal and vertical; automatic control differential setting; final status of any remote monitoring equipment; ac supply voltage; adjusted dc output voltage; and total protective current.

-- End of Section --