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USACE / NAVFAC / AFCEC / NASA **UFGS-26 42 19.10 (November 2008)**

Preparing Activity: USACE **Superseding**
UFGS-26 42 19.10 (April 2006)

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated January 2023
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DIVISION 26 - ELECTRICAL

SECTION 26 42 19.10

CATHODIC PROTECTION SYSTEMS (IMPRESSED CURRENT) FOR LOCK MITER GATES

11/08

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SECTION 26 42 19.10

CATHODIC PROTECTION SYSTEMS (IMPRESSED CURRENT) FOR LOCK MITER GATES
11/08

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NOTE: This guide specification covers the requirements for cathodic protection systems for lock miter gates. This section was originally developed for USACE Civil Works projects.

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

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NOTE: Cathodic Protection should be installed on those portions of the gates submerged at normal pool levels. The faces of the gates should be protected to upper pool stages, except that the downstream face of the lower gates must be protected to the lower pool level.

This guide specification includes the technical requirements for the types of equipment normally provided in a cathodic protection system, and is based upon the premise that the system is designed by a qualified engineering firm hired by the Government to provide a complete cathodic protection

system design, including detailed specifications (which contain performance criteria) and drawings which the successful Contractor can then use to construct the system. The engineering firm must provide the design services of a Corrosion Expert(s) to design, supervise, and inspect system installation and test, energize, and adjust the completed system installation. The Corrosion Expert is 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 of Lock & Dam Miter and Tainter Gates and other submerged metallic appurtenances. Such person(s) must be accredited or certified by NACE International (formerly the National Association of Corrosion Engineers) as a Corrosion or Cathodic Protection (CP) Specialist or be a register professional engineer who has certification or licensing that includes education and experience in corrosion control of Lock & Dam Miter and Tainter Gates and other submerged metallic appurtenances. The names and qualifications of the Corrosion Expert(s) must be certified and submitted in writing to the Contracting Officer prior to the start of the cathodic protection system design.

It is the intent of these guide specification to require the Contractor to design, furnish, install, test and place into service the complete cathodic protection system for the lock miter gates. The system is to consist of all equipment, wiring, and wiring devices necessary to produce a continuous flow of direct current from the anodes in the water electrolyte to the gate surfaces to adequately and efficiently protect the surfaces of the metal structures against corrosion where the surfaces are in contact with the water. The metallic surfaces of the gates need only be protected to upper pool stages, except protect the downstream side of the lower gate to lower pool level. This is in addition to the protective coating on the gates. The Contractor will provide, prior to system installation, detailed design calculations, bill of materials lists and drawings of the cathodic protection system. The drawings will detail the system installation including arrangement and locations of all anodes, terminal boxes, conduit routing and test facilities to be installed for corrosion control on the submerged surfaces of the gates. The Contractor furnished materials list, design calculations and drawings must be approved by the Contracting Officer prior to purchasing, delivering or installing any of the cathodic protection system. These specifications together with the approved materials list, design calculations and drawings provide the minimum requirements of this contract. The cathodic

protection system will be furnished complete and in operating condition as further defined later in this specification.
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1.1 UNIT PRICES

Measurement and payment requirements will be specified for work subject to extreme variation in estimated quantity when unit price bidding is required.

1.2 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.

If the Contractor desires, for any reason, to deviate from or utilize publications other than those designated below, submit to the Contracting Officer, for review and approval, the requested deviation and/or the publication proposed for use. Clearly state the requested deviation and the reasons for it, including a complete comparison and cross-reference in sufficient detail to prove compliance to the applicable portions of the publications referred to herein and listed below.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI C39.1	(1981; R 1992) Requirements for Electrical Analog Indicating Instruments

ASTM INTERNATIONAL (ASTM)

ASTM A518/A518M	(1999; R 2022) Standard Specification for Corrosion-Resistant High-Silicon Iron Castings
ASTM D789	(2015) Determination of Relative Viscosity and Moisture Content of Polyamide (PA)

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

NACE INTERNATIONAL (NACE)

NACE SP0169	(2013) Control of External Corrosion on Underground or Submerged Metallic Piping Systems

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

ANSI C80.1	(2020) American National Standard for Electrical Rigid Steel Conduit (ERSC)
NEMA 250	(2020) Enclosures for Electrical Equipment (1000 Volts Maximum)
NEMA FB 1	(2014) Standard for Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit, Electrical Metallic Tubing, and Cable
NEMA FU 1	(2012) Low Voltage Cartridge Fuses
NEMA ST 1	(1988; R 1994; R 1997) Specialty Transformers (Except General Purpose Type)
NEMA ST 20	(2014) Dry-Type Transformers for General Applications
NEMA TC 2	(2020) Standard for Electrical Polyvinyl Chloride (PVC) Conduit

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

NFPA 70	(2023) National Electrical Code

U.S. ARMY CORPS OF ENGINEERS (USACE)

CERL Tech Rep FM-95/05	(1994) Field Evaluation of Cathodic Protection Systems Using Ceramic-Coated Anodes for Lock and Dam Gates
EM 1110-2-2704	(2021) Engineering and Design -- Cathodic Protection Systems (CPS) for Civil Works (CW) Structures

UNDERWRITERS LABORATORIES (UL)

UL 489	(2016; Rev 2019) UL Standard for Safety Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures

1.3 SYSTEM DESCRIPTION

1.3.1 General Description

Furnish, install, test and place in service a complete cathodic protection system for the lock miter gates consisting of all equipment, wiring, and wiring devices necessary to produce a continuous flow of direct current from the anodes in the water electrolyte to the gate surfaces to, adequately and efficiently, protect the surfaces of the metal structures against corrosion where the surfaces are in contact with the water. The metallic surfaces of the gates need only be protected to upper pool stages, except protect the downstream side of the lower gate to lower pool level. This is in addition to the protective coating on the gates.

a. Provide, prior to system installation, detailed design calculations, bill of materials lists and drawings of the cathodic protection system. The detailed drawings must show the system installation including arrangement and locations of all anodes, terminal boxes, conduit routing and test facilities to be installed for corrosion control on the submerged surfaces of the gates. Six copies each of detail drawings of the proposed cathodic protection system installation, proposed bill of materials, and Contractor design calculations within [30] [45] [90] [_____] days after receipt of notice to proceed, and before commencement of any work. Provide dimensions and show anode arrangement for both elevated and sectional views of the gates, rectifier details and locations, terminal box details and locations, mounting details, wiring diagram, conduit layout locations, types and transitions and any other pertinent information considered necessary for the proper installation and performance of the system.

b. The Contractor's furnished materials list, design calculations and drawings are subject to approval by the Contracting Officer prior to purchasing, delivering or installing any of the cathodic protection system. These specifications together with the approved materials list, design calculations and drawings provide the minimum requirements of this contract.

c. Furnish cathodic protection system complete and in operating condition as further defined later in this specification.

1.3.2 Performance Requirements

Final test and adjust the system such that the cathodic protection system is providing corrosion control for the submerged surfaces of the lock miter gates in accordance with the following paragraphs taken from Section 6 of NACE SP0169.

1.3.2.1 First Criterion

A negative (cathodic) voltage of at least a minus 850 millivolts "instant-off" potential, as measured with respect to a calibrated, saturated copper-copper sulfate reference electrode (CSE) over 90 percent of each gate leaf face, and at least minus 800 millivolts "instant-off" at all other locations. These requirements do not necessarily include those areas within 0.61 m 2 ft of the sill, quoin and miter of each gate (refer to Paragraph 1.3.3.2 of NACE SP0169). Achieve the above criteria without the "instant-off" potential exceeding minus 1100 millivolts at any location. Determine this voltage with the cathodic protection system in operation. Make correction for IR drop using "instant-off" potential measurements (interrupt all operating cathodic protection systems simultaneously). If digital meters are used to obtain these measurements, interpret the second reading displayed on the digital voltmeter after interruption of the rectifier current as the "instant-off" reading.

1.3.2.2 Second Criterion

A second criterion may be used for those gate submerged surfaces within 0.61 m 2 ft of each gate sill, quoin, and miter to ensure that the operating conditions are providing cathodic protection. This criterion is a minimum cathodic polarization voltage decay of 100 millivolts provided that a potential of at least minus 750 millivolts "instant-off" potential as measured with respect to a calibrated, saturated copper-copper sulfate reference electrode (CSE) is also obtained. Make polarization shift measurements within 0.305 m 1 ft of the sill plate at the quoin, at 0.61 m 2 ft intervals along the gate bottom, and at the miter on each gate leaf face. This criterion cannot be used until the criterion in paragraph 1.3.3.1 of NACE SP0169 for the remaining gate submerged surfaces have been maintained for a minimum 1-week period. This allows time for the cathodic protection system to polarize the gate metal. Measure "instant-off" potential between the structure surface and a saturated copper-copper sulfate reference cell immersed in the electrolyte directly adjacent to the structure. Determine this polarization voltage shift by interrupting the protective current and measuring the polarization decay thereafter. When the protective current is initially interrupted, an immediate voltage shift will occur. Record and use the second voltage reading observed after the immediate voltage shift as the base reading from which to measure polarization decay. Then take readings each 10 minutes thereafter and record the voltage readings and time intervals. The total time for achieving this decay is 4 hours or less.

1.3.3 Contractor Quality Control

1.3.3.1 General

Establish and maintain quality control for all operations to assure compliance with contract requirements and maintain records of this quality control for all construction operations, including, but not limited to, the following:

a. Design
b. Materials
c. Assembly and workmanship
d. Installation
e. Testing

1.3.3.2 Reporting

Furnish the original and two copies of these records and tests, as well as corrective action taken, [daily] [_____] to the Contracting Officer.

1.3.4 Modification of Design

Do not modify the design of the cathodic protection system as specified and shown on the Contractor's approved drawings except with the express written approval of the Contracting Officer. Submit all Contractor identified discrepancies in the design or any change proposals with sufficient details for complete evaluation by the Contracting Officer. Meet the minimum design requirements specified herein. Fully describe and submit such proposed modifications to the Contracting Officer for approval. The Contractor is responsible for the satisfactory performance of the furnished complete systems. Identify proposed modifications or changes as a "MODIFICATION" or "CHANGE" and submit to the Contracting

Officer for approval within 15 days after the need for such modification or change is determined.

1.4 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.

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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

Detailed Drawings; G[, [_____]]

SD-03 Product Data

Materials and Equipment; G[, [_____]]

Training Course; G[, [_____]]

Protective Angle Irons; G[, [_____]]

Modification of Design; G[, [_____]]

SD-06 Test Reports

Factory Test Data

System Commissioning; G[, [_____]]

SD-07 Certificates

Qualifications; G[, [_____]]

SD-10 Operation and Maintenance Data

Operation and Maintenance Instructions; G[, [_____]]

1.5 QUALITY ASSURANCE

1.5.1 Qualifications

Perform cathodic protection system installation, including all testing, energizing and placing of system in service, by an organization that has had a minimum of 5 years' experience in this type of work. Use Corrosion Expert whose credentials meet or exceed those provided for below to supervise the installation and testing of this system. Submit certified Corrosion Expert(s) qualifications for all personnel who may be used to fulfill this position on the project. Installation of the cathodic protection system will also be witnessed by the Contracting Officer. Provide certified information with their submittals evidencing their compliance with this organization experience requirement.

1.5.2 Contractor's Responsibilities

Provide the services of a Corrosion Expert to design, supervise installation, test and final adjust the miter gate cathodic protection system for operation in accordance with these specifications. Inspect all work associated with the system installation, certify all work prior to system energization and be present and participate in all system testing and final adjusting.

1.5.3 Corrosion Expert

"Corrosion expert," as used in this specification, is 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 of submerged metal structures. Ensure such a person is accredited or certified by the National Association of Corrosion Engineers (NACE) as a NACE Accredited Corrosion Specialist or a NACE certified Cathodic Protection (CP) Specialist or is a registered professional engineer who has certification or licensing that includes education and experience in corrosion control submerged metallic structures, if such certification or licensing includes 5 years' experience in corrosion control on metallic structures of the type under this contract.

1.5.4 Pre-Installation Meeting

Conduct a pre-installation meeting, attended by the Contractor's project superintendent and corrosion expert, at the project site office. Hold this meeting after all pre-construction submittals have been made and approved by the Contracting Officer prior to the start of any work on this project. Include discussions of Safety, Communication and Work Plans, as well as any other issues which may have risen as a result of the submittal review.

1.6 DELIVERY, STORAGE, AND HANDLING

The Contracting Officer will arrange to provide an unsecured area onsite for the Contractor to store the system materials and installation equipment. The area's size will be limited to approximately [_____] square meters square feet. Provide storage means to secure the equipment against loss due to theft and/or weather, fire or floods.

1.7 PROJECT/SITE CONDITIONS

Coordinate and properly relate the work to the site and to all trades. The location and dimensions of the gate structures to receive protection are available from the Contracting Officer. The cathodic protection system design is based on a water resistivity of [_____], a total area, in square meters feet, of [_____], a minimum coating efficiency of 50 percent, a minimum current density requirement for effective cathodic protection of [_____] amperes/bare square meter foot of submerged steel and a 20-year life expectancy.

1.8 WARRANTY

Gurantee materials, equipment, and workmanship furnished under this section of the specifications for a period of 1 year from the date of acceptance. Prior to expiration of the warranty period, the Government will conduct a System voltage and current output test of the cathodic protection system including each anode output installed on the lock gate structure as well as detailed "On" and "Instant-Off" structure to electrolyte potential measurements to determine if the system and equipment are performing in accordance with the plans and specifications and that no significant deterioration of the system or components therein has occurred during the first year of operation. Acknowledge responsibility under these guarantee provisions by letter, stating that the equipment, materials, and workmanship referred to herein are guaranteed to continue to perform as installed and to continue to provide effective corrosion control in accordance with the criteria elsewhere in these specifications and specifically indicating the inclusive dates of the guarantee period starting at the date of final acceptance of the correctly working system approved by the government and for a period of 1 year thereafter.

1.9 SYSTEM COMMISSIONING

1.9.1 General

Perform the following system energizing and commissioning tests. Perform all energizing and commissioning tests in the presence of the Project Corrosion Engineer, recorded and submitted to the Contracting Officer within [_____] days following completion of the test. Submit all installation and energization measurements and test data in tabulated form. Notify the Contracting Officer 30 days in advance of the date of the test so that a representative can be present. Ensure all instruments used in conducting the tests have been calibrated by an accredited testing laboratory within 1 year prior to the test. Provide certification to the Contracting Officer for approval.

1.9.2 Insulation Testing

After installation of the button anode on the gate, but prior to connection to the rectifier and submergence, make an insulation test to demonstrate that no metallic contact or short circuit exists between the anode and the structure. Make these tests using a Megger apparatus or other device specifically designed for this purpose. Replace insulation found to be shorted. Ensure each button anode has a minimum resistance of 500,000 ohms isolation from the gate. If the button anode fails to indicate 500,000 ohms isolation, make the necessary corrections and/or modifications to the anode installation to achieve the minimum reading.

1.10 EXTRA MATERIALS

a. Furnish spare rod, sausage and button-type anodes (the type used in the original installation) to the Contracting Officer with a minimum of five of each type installation component required for the original installation of the sausage and button anodes. Furnish sufficient neoprene gaskets, mounting hardware, and epoxy cement for installation of the silicon button anodes. Supply a minimum of two of each type of anode rod or string assemblies each for the upstream and downstream gates (anode assembly complete with factory attached 30.48 m 100 ft anode lead cable and a minimum of five disk or button anodes with 30.48 m 100 ft of factory attached cable). Supply cement, epoxy, polychloroprene gaskets, and any other material needed for installation in sufficient quantity to install these spare components.

b. Furnish a complete set of special tools, provided in a steel or plastic toolbox, for use in installing all types of anodes used in the installation. Tools used in making the original installation, provided they are in good working condition, will be acceptable. Ensure one tool is a torque wrench device capable of 275.79 kPa 40 psi.

PART 2 PRODUCTS

2.1 MATERIALS AND EQUIPMENT

Ensure all cathodic protection system materials and equipment furnished is designed for a minimum 20-year service life when operating at the system maximum rated output. Use components that are based on the Contractor's Cathodic Protection System Specialist's design which is in accordance with these specifications. Submit a complete list in triplicate of materials and equipment to be incorporated in the work, within [30] [45] [90] [_____] days after date of receipt of notice to proceed, and before commencement of installation of any materials or equipment. Include cuts, diagrams, and such other descriptive data as may be required by the Contracting Officer. Partial lists submitted from time to time will not be considered. Submit, as a minimum, the following:

a. Water resistivity as measured on site.

b. As a minimum, provide complete system design calculations as provided in Appendix "K" of CERL Tech Rep FM-95/05 including calculations for total current required for each gate side, each anode circuit resistance, rectifier current and voltage output requirements and life of each anode type and location within the system.

c. Complete list of materials for all cathodic protection system components including all replaceable components in the rectifier units, terminal boxes and anodes materials with mounting equipment including part numbers and source name, address and phone number for each component.

d. Conductor types and sizes including copper grade, number of strands, insulation, and resistance for each wire type and size to be used.

e. Anodes, layout of anodes, and detailed description of anode installation procedure.

f. Layout of rectifiers and anode terminal boxes, rectifier and terminal box details including method of control including wiring diagram and schematic, output measurement means, cabinet materials and construction, ammeters and voltmeters, shunt resistors, variable resistors, and AC & DC lightning and surge protection.

g. All connections, supports, and seals for conductors, conduit, and plastic and steel protector pipes, pipe caps, angle iron, [_____].

h. All watertight connections and connection protection means.

i. Resistor and anode terminal cabinet details and mounting locations. Show identified connections and conductors in the terminal cabinet on a drawing.

j. Certified experience and qualification data of installing firm, as specified in paragraph QUALIFICATIONS.

2.1.1 Direct Current Cables

****

NOTE: Low-density, high-molecular-weight, polyethylene (HMPE) insulation conforming to ASTM D1248, Type I, Class C, Grade 5, Grades E-5 and J-1, should be specified for all exposed cable or cable to be installed in conjunction with rod or string anode protective conduit. High-density polyethylene is not recommended because it is subject to stress cracking. Polyvinyl chloride (PVC) insulation is not recommended because it is a relatively soft and easily damaged insulation and does not have the required tight fit on the wire, which can provide a path for moisture ingress and corrosion attack on the wire

****

2.1.1.1 Anode Lead Cables

Provide direct current cable from the terminal cabinet to each anode disk, ribbon, button or rod assembly consisting of 7-strand No. 8 AWG stranded copper wire with type CP high molecular weight polyethylene insulation (HMPE), 2.78 mm 7/64 inch thick, 600-volt rating, in accordance with ASTM D1248, Type I, Class C, Grades E-5 and J-1. Each anode lead must be continuous without splices from its point of connection in the terminal cabinet to the anode disk, ribbon, button, or rod assembly. Assemble cable-to-anode connection by the manufacturer and the seal area with a waterproof epoxy. Ensure cable-to-anode contact resistance is 0.003 ohm maximum. Also assembleHSCI string anode assemblies (assembled in link sausage manner to the anode cable lead) by the manufacturer. Ensure conductor for the HSCI sausage strings only are 7-strand, No. 4 AWG copper wire with CP high molecular weight polyethylene insulation (HMPE), 2.78 mm 7/64 inch thick, 600-volt rating, in accordance with ASTM D1248, Type I, Class C, Grades E-5 and J-1, and do not cut or splice within the anode or assembly and route without splicing to the anode terminal box. The cable HMPE insulation does not adhere well to some epoxies; rough in the sealant area prior to application of the sealant to the anode connections. Mark anode leads, terminal board connections, and corresponding jumpers on the front of the terminal board with the anode number, as specified.

2.1.1.2 Rectifier and Terminal Cabinets Connection Cables

Provide soft drawn copper conductorsand have the number of conductors as shown on the drawings. Cables connecting the terminal cabinet to the lock wall outlet and cables between the lock wall outlet and the rectifier dc terminals must be No. 10 AWG insulated copper wire with a neoprene jacket. Provide cables between the resistor and anode terminal cabinets on each gate consisting of 7-strand No. 8 AWG stranded copper wire with type CP HMPE, 2.78 mm 7/64 inch thick, 600-volt rating, in accordance with ASTM D1248, Type I, Class C, Grades E-5 and J-1. Include one conductor for each dc plus circuit and one conductor for each negative connection. Make each cable continuous without splices from its point of connection in one terminal cabinet to its point of connection in the other terminal cabinet.

2.1.2 Cable in Conduit

Provice cathodic protection cables consisting of soft drawn copper conductors with Class B stranding and a [low-density, high-molecular-weight black polyethylene] [RHW-USE Style RR Hypalon] covering serving as both insulation and jacket. Provide cables that meet or exceed the requirements specified above. Make flexible cable connections between the ac power outlet on the lock wall and the ac input terminals of the rectifier with No. 10 AWG copper conductors in flexible portable power cables, UL type SO.

2.2 RECTIFIERS AND AUXILIARY EQUIPMENT

2.2.1 General

Provide a rectifier unit for [each upstream and downstream face of each gate leaf] [each of the four gate leaves of the lock]. Provide cathodic protection system power circuit consisting of a step-down transformer with secondary taps for output adjustment, primary circuit breaker, rectifier transformer, rectifier, secondary fuses, and rectifier terminal panel. Locate rectifier units [in the control houses] [outside at the specified locations]. Design units [for removal during periods when flood waters overtop the lock wall] [to be free-standing].

2.2.2 Cabinets

****

NOTE: Air-cooled rectifiers are used for most

applications. Oil immersion cooled units are normally on used in highly corrosion atmospheres.

The rectifier cabinet may be located in the control house to avoid problems caused by moisture, insects, dust, vandalism, etc., when these are a factor. When outside placement of the rectifier is indicated, the rectifier must be securely mounted or fastened to the structure (see Alternate 2 below). When high-water flooding is likely, the rectifier should be mounted on wheels for easy removal (see Alternate 1 below). It is left to the designer to provide detailed drawings for either type rectifier installation. Adequate drainage must be provided in all terminal cabinets since flooding will in most cases cause sand and water to accumulate in the terminal cabinet. Eventually, this will cause the appearance that anodes are failing when, in fact, contacts in the terminal cabinets, or rectifier contacts, are causing failure and outages to the cathodic protection systems. Alternatively, watertight sealed terminal cabinets can be used. The rectifier cabinet referenced in these documents is for the air-cooled type transformer and rectifier unit. If the designer selects the oil-immersed type unit, then the specifications will have to be revised accordingly.

****

Provide rectifier cabinet to house the rectifier transformer, rectifier stacks, circuit breaker, terminals, and the control and instrument panel. In installations requiring the use of a step-down transformer, design the cabinet such that the rectifier equipment specified above can be installed in the lower section of the cabinet with the step-down transformer in the upper portion. Provide [convection air cooled] [oil immersed cooled] cabinets constructed of 1.894 mm 14-gauge minimum sheet stainless steel, ASTM grade 304. Design the cabinets for use outdoors; NEMA 250, enclosure 3R, and use appropriate structural shapes in the construction of the cabinet to provide rigidity and to prevent bending or flexing of the cabinet while being transported. Provide louvers for air-cooled units in the hinged doors and on the sides of the cabinets for ventilation. Cover all ventilation openings with ASTM grade 304 stainless steel insect screen arranged so as to be easily replaceable. Hinge all doors using post hinges designed to allow easy removal of all doors for unit servicing and provide with a hasp and lock for padlocking. Use locks that are keyed alike such that all cabinets can be opened with one key. Furnish the keys and turn them over to the Contracting Officer.

2.2.3 Wheeled Rectifier Cabinets (Alternate 1)

Mount rectifier cabinet on wheels and provide with handles for moving during floods. Ensure wheels, axles, and bearings have sufficient capacity to support a weight of at least three times the weight of the complete rectifier. Weld studs for the clamps to be used for securing the rectifier to the pipe rail, as shown on the drawings, to a reinforced back section of the cabinet at the factory before finishing. All components must be ASTM grade 304 SS or equal.

2.2.4 Stationary Cabinets (Alternate 2)

Mount rectifier cabinet on structures as shown on the drawings. Accomplish welding of ASTM grade 304 SS or equal clamps, brackets, or cabinet-back reinforcement at the factory before finishing.

2.2.5 Circuit Breakers

Install a 120/240-volt, [10] [_____] ampere-interrupting-capacity, double-pole, molded-case circuit breaker conforming to UL 489 in the primary circuit of the rectifier transformer and disconnect both conductors. Provide breaker with instantaneous and inverse time trips. Provide [10] [_____] ampere cartridge-type fuses conforming to NEMA FU 1 with suitable fuse holders in each leg of the dc circuit.

2.2.6 Step-down Transformers

Provide step-down transformers of the two-winding, insulating dry type conforming to NEMA ST 20 rated for 480-120/240 volts, single-phase, 60-Hertz. Provide transformers with 2 to 5 percent full capacity primary taps below rated voltage. Ensure transformers rated for no less than a temperature rise of 80 degrees C 176 degrees F above a 40 degrees C 104 degrees F ambient and provide with Class B or H insulation.

2.2.7 Rectifier Transformers

Provide two-winding, [convection air-cooled] [oil immersed cooled] rectifier transformer, with a primary operating voltage of 120/240 volts, single phase, and conforming to the requirements of NEMA ST 1. Provide transformer secondary with five "coarse" and five "fine" taps on each dc circuit, to permit variations of the dc output voltage in 25 uniform increments of the rated output voltage, from zero to a maximum rated voltage of [_____] volts. Adjust voltage steps by rotating solid brass tap bars. Identify each control by suitable permanent, engraved marking such as "coarse" or "fine" with an arrow to indicate the type and direction of adjustment. Mark individual steps of adjustment with numbers in consecutive order for fine control and with letters in alphabetical order for coarse control. Mount all primary alternating current terminals behind the panel. Dip coils of all transformers manufactured for cathodic protection use in preheated varnish and bake dry for maximum moisture and corrosion resistance.

2.2.8 Rectifiers

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NOTE: Silicon rectifier stacks are usually recommended for the rectifier and these specifications reflect their use; however, the designer has the option to select either selenium or silicon stacks. When the specification writer selects selenium, the specifications should be revised accordingly. The advantages and disadvantages for the two types of rectifier stacks are as follows:

Silicon stacks (diodes): These stacks are more economical in higher voltage output circuits and in higher current circuits.

Advantages:

a. Cost-effective in high current ratings.
b. More efficient in higher voltage ratings.
c. Replacement cells are easily stocked.
d. Higher efficiency

Disadvantages:

a. Must be surge protected with selenium.
b. Cannot withstand extreme surges.

Selenium stacks (cells): These stacks may be more economical in lower voltage output circuits where current requirements are lower.

Advantages:

a. Can withstand surges caused by lightning much better than silicon without additional protecting devices.
b. Are cost-effective in lower voltage and lower current ratings.
c. Can withstand severe short-term overloads

Disadvantages:

a. Expensive in high voltage and high current ratings.
b. Cannot be easily replaced
c. May be difficult to obtain.
d. Replacement stacks can be expensive to stock.
e. Relatively low efficiency

Recent studies by the US Army Corps of Engineers indicate that remote monitor of these systems can greatly improve the reliability of effective monitor and maintenance of these systems and eliminate the need for meters in the units:

"Demonstration of Remote Monitoring Technology for Cathodic Protection Systems" FEAP-TR 97/76 (April 1997), http://owww.cecer.army.mil/TechReports/Vancatho/Vancatho.pdf

"Demonstration of Remote Monitoring Technology for Cathodic Protection Systems: Phase II" FEAP-TR 98/82 (May 1998), http://owww.cecer.army.mil/techreports/van_cpr2/van_cpr2.flm.post.pdf

"Remote Monitoring Equipment for Cathodic Protection Systems" FEAP User Guide 97/75 (April 1997), http://owww.cecer.army.mil/TechReports/Vancprem/Vancprem.pdf

"User Guide for Remote Monitoring Equipment for Cathodic Protection Systems: Phase II" FEAP User Guide 98/77 (May 1998), http://owww.cecer.army.mil/techreports/VANFUG2.CPR/vanfug2.cpr.post.pdf

The designer should investigate the cost, reliability and availability of these remote monitoring systems.
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Provide [air-cooled] [oil-immersed] units, consisting of silicon stacks to provide full-wave, bridge-type rectification, within the manufacturer's ratings. The rectifier must be suitable for operation over an ambient temperature range of -18 to 49 degrees C 0 to 120 degrees F. Use output ratings as designed by the Corrosion Expert and for continuous duty operation.

2.2.9 Ammeter and Voltmeter

Provide a dc ammeter and voltmeter of the semi flush, 89 mm 3-1/2 inch round or rectangular panel board type, conforming to the applicable requirements of ANSI C39.1, in each dc circuit, or as otherwise indicated on the drawings. Provide sealed, taught band type instruments with a guaranteed accuracy of 1 percent of full-scale deflection, zero adjustment, and a minimum scale length of 61 mm 2.4 inch. Indicate full load reading by means of a red mark on the meter scale and incorporate at least 80 percent of the meter scale length. Provide each meter with a momentary contact switch, either integral with the meter or separately mounted, for momentary reading. A single meter having dual scales may be furnished in lieu of separate meters, provided that the scales are distinct and easily read, and that a switch is provided to select the desired function and to prevent simultaneously energizing more than one function.

2.2.10 Current Monitoring Shunt

Provide a separate current monitoring shunt resistor on the rectifier unit face plate to facilitate using an external digital milli-voltmeter to confirm the current output displayed by the unit ammeter. This shunt resistor must have a calibrated accuracy of plus or minus 1 percent and a 1 ampere/millivolt drop rating.

2.2.11 Ammeter and Voltmeter Switches

Use switches for switching the meters in and out of the dc circuit that are lever action sealed toggle, quick make-or-break type switches. Ensure switches are [[single-pole] [double-throw]] [[double-pole] [double-throw]] and wired not to interrupt the output circuit.

2.2.12 Control and Instrument Panel

Provide dead-front type control and instrument panel and install in the rectifier cabinet. Make primary connection by means of a panel-mounted terminal block with screw connection protected by a removable metal or molded plastic cover. Terminate incoming power lines in such a manner as to prevent accidental contact by personnel using the rectifier.

2.2.12.1 Tap Bars

Permanently identify tap bars serving the rectifier transformer secondary adjustment by means of engraving on the non-metallic control panel face plate denoted "coarse" and "fine" and identify the individual tap positions by letters, such as "A," "B," "C," and numerals, such as "1," "2," "3," respectively.

2.2.12.2   DC Output Terminals

Identify rectifier dc output terminals by means of engraving on the non-metallic control panel face plate indicating polarity of the terminal and point of connection to the system, i.e., "+ANODES" and "-STRUCTURE."

2.2.12.3   Components Identification

Identify all other components on the rectifier panel face plate by means of engraving on the non-metallic control panel face plate.

2.2.13   Anode Cable Leads

Identify anode cable leads at the resistor and anode terminal cabinet by means of plastic sleeves or tags showing the anode lead number as indicated on the drawings. Ensure they are of sufficient length so that splicing between the anode and the anode terminal box is not necessary. No splices of the anode lead wires will be permitted between the anode and the anode terminal box.

2.2.14   Surge Arresters

Provide MOV surge arresters for all AC and DC power circuits. In addition, for AC voltages above 120-volt, use a single pole valve-type surge arrester for each input line. Locate it ahead of the ac breaker feeding the rectifier transformer. Use surge arresters rated for continuous load currents up to [10] [_____] amps minimum and limit the voltage to 200 volts peak. The response clamping activation time is 5 nanoseconds maximum.

2.2.15   Wiring Diagram

Encase s complete wiring diagram of the rectifier unit showing both the ac supply and the dc outputs to the resistor and anode terminal cabinets in clear rigid plastic and mount on the inside of the rectifier cabinet door. Show and label all components.

2.2.16   Resistor and Anode Terminal Cabinet Wiring Diagram

Provide a complete wiring diagram showing the anode numbers in the terminal cabinets and a complete wiring diagram of the entire cathodic protection system. Identify each conductor and each termination.

2.3   CONDUIT AND FITTINGS

2.3.1   Nonmetallic Conduit

Nonmetallic conduit must be type 80, extra heavy-wall, PVC, rigid-plastic conduit. Provide conduit conforming to the requirements of NEMA TC 2. PVC conduit utilized as rod or string anode protective pipe is the only PVC conduit allowed by these specifications. Design the plastic pipe such that its inside diameter (I.D.) is at least 51 mm 2 inch greater than the anode outside diameter (O.D.). Provide perforated pipe on the side opposite the angle iron protective channel except for the area within 51 mm 2 inch of the pipe couplings at each girder web which must not be perforated. The total open area provided by these perforations must be at least equal to the surface area of the anode material contained within the PVC pipe.

2.3.2 Rigid Metal Conduit

Provide rigid metal conduit conforming to the requirements of ANSI C80.1, and of the size indicated on the drawings. Galvanize conduit both inside and outside using the hot-dip method.

2.3.3 Conduit Fittings and Outlets

Provide conduit fittings and outlets for rigid metal conduit conforming to the requirements of NEMA FB 1.

2.4 RESISTOR AND ANODE TERMINAL CABINETS

Provide terminal cabinets for each rectifier output circuit. Provide NEMA type 4X cabinets consisting of weather-resistant construction. Construct cabinets of ASTM grade 304 stainless steel. Provide cabinets of ample size to accommodate all anode and power input lead wires and [_____] standard brass or copper heavy duty screw terminals to facilitate individual connection of each anode assembly lead wire through a 0.01 ohm type RS shunt resistor to a common copper bus bar. Mount all terminals, bus bars, shunts, and other DC conducting components to an extra strong, non-metallic panel. Identify all conductors in the cabinet by means of plastic or metal tags or plastic sleeves to indicate the anode number. Identify each terminal with permanent engraved identification of the anode number, or other corresponding conductor numbers, or function. Mount cabinets securely on the top of the corresponding gate in the manner proposed by the Contractor and approved by the Contracting Officer. Provide a removable, hinged front door facing a direction after installation that is easily accessible.

2.5 IMPRESSED CURRENT ANODES AND MATERIALS

2.5.1 General Requirements

For details on various types of anodes, anode designs and typical anode configurations for preparation of project drawings, refer to CERL Tech Rep FM-95/05.

2.5.2 Ceramic Precious Metal Oxide Coated Anodes

Provide ceramic precious metal oxide coated anodes conforming to the following requirements:

2.5.2.1 Conductive Precious Metal Oxide Ceramic Coating

Use electrically conductive ceramic coating that contains a mixture consisting primarily of iridium, tantalum, and titanium oxides. Although the exact composition of the conducting layer can vary, the average composition must generally be a 50/50 atomic percent mixture of iridium and titanium oxides with small amounts of tantalum. Use coating resistivity certified by the manufacturer to have an electrical resistivity of less than 0.002 ohm-centimeters, a bond strength to the substrate metal greater than 50 MPa, and a current capacity of 100 DC amperes per square meter of anode surface area when operated in an oxygen-generating electrolyte at 65.5 degrees C 150 degrees F for 20 years.

2.5.2.2 Anode Substrate Material

Fabricate anode substrate from high purity alloy titanium.

2.5.3 Hi-Silicon Cast-Iron Anodes

Provide hi-silicon cast-iron anodes conforming to the following requirements:

2.5.3.1 Chemical Composition (Nominal)

ELEMENT	PERCENT BY WEIGHT
Silicon	14.20 - 14.75
Manganese	1.50 Max
Carbon	0.75 - 1.15
Chromium	3.25 - 5.00
Iron	Balance

2.5.3.2 Electrical Resistivity

Electrical Resistivity must be 72 micro-ohm-centimeter at -7 degrees C 20 degrees F maximum.

2.5.3.3 Physical Properties (Nominal)

PROPERTY	VALUE
Tensile Strength	1.05 $kg/m^2$15,000 psi
Compressive Strength	7.04 $kg/m^2$100,000 psi
Brinnell Hardness	520
Density	7.0 $g/cm^3$0.253 lb/cu in.
Melting Point	1,260 deg C2,300 deg F
Coefficient of Expansion Between 0 deg C and 100 deg C 32 deg F and 212 deg F	0.00000733 cb/deg C0.00000289 in/deg F

2.5.4 Ceramic Coated Titanium Anodes (Disk Type)

2.5.4.1 General

Ceramic coated titanium disk anodes must be conductive ceramic coated titanium disks similar to that shown in Figure 2, "Typical Ceramic Coated Flat Disk Anode" of CERL Tech Rep FM-95/05, November, 1994. Provide anodes conforming to the requirements in Section 2.6.1 that are suitable for cathodic protection use, highly resistant to corrosion, and with good electrical properties. Ensure anodes disk is at least 127 mm 5 inch diameter factory mounted in a 305 mm 12 inch diameter FRP reinforced Polyurethane protective shield to prevent shorting of the anode to the skin plate and over voltage damage to the adjacent coating. Provide it with an integral titanium mounting rod with gold plated connector socket. Provide each disk anode with a gold plated connector plug and PVC cable connector that is assembled by the manufacturer. Submit certified Factory Test Data on anode connections showing anode-to-contact resistance. Provide a measured resistance of less than 0.003 ohm (or redo the connection). Provide a certified report on these factory tests within two weeks after fabrication by the manufacturer.

2.5.4.2 Impact Protection for Disk Anode Cables

Weld a 152.4 mm 6 inch diameter by 203.2 mm 8 inch long steel schedule-40 pipe with threaded pipe cap to the gate in back of each disk anode. Drill a hole in the side of this pipe and weld a thread-o-let fitting to the 152.4 mm 6 inch diameter pipe at this point to receive the anode lead wire and conduit routed to the anode terminal box at the top of the gate leaf. The pipe and conduit are provided for impact protection of the anode cables and the anode bolt. Galvanize and paint the pipes with 0.1778 mm 7 mil of paint.

2.5.4.3 Number of Ceramic Coated Titanium Disk Anodes

Provide the actual number of ceramic coated titanium disk anodes in accordance with the corrosion engineer's approved design calculations based on the system circuit resistance, current requirements ,current distribution and anode life, in accordance with EM 1110-2-2704 and Appendix "A" in CERL Tech Rep FM-95/05, "Detailed Cathodic Protection Design Procedures for Pike Island Auxiliary Lock" as long as the minimum number of button anodes provided must equal or exceed one each for every 18.58 square meters 200 square feet of submerged steel surface area (for some typical anode configurations, refer to Figures 4, 5, 6, 7, C3, and F2 in CERL Tech Rep FM-95/05). The minimum number of anodes and an indication of their mounting locations should be shown in the design drawings.

2.5.5 Hi-Silicon Cast Iron Button Anodes

2.5.5.1 General

Provide high-silicon cast iron anodes conforming to ASTM A518/A518M.

2.5.5.2 High-Silicon, Cast-Iron Anodes (Button Type)

Provide high-silicon, cast-iron "button-type" anodes consisting of an alloy of silicon, carbon, manganese, and iron. Ensure anodes are similar in all respect to the Button anode design shown in Figure 1, "HSCBCI "Sausage" and "Button" Anode Designs of CERL Tech Rep FM-95/05. Ensure anodes conform to the requirements in paragraph IMPACT PROTECTION FOR RODS AND SAUSAGE-STRING ANODES and are suitable for cathodic protection use, are highly resistant to corrosion, and have good electrical properties. Provide anodes button castings with a nominal weight of 8.16 kg 18 lb and a size of 152.4 mm 6 inch diameter by 76.2 mm 3 inch deep and provide with a 19.05 mm 3/4 inch diameter by 50.8 mm 2 inch deep conical terminal connection cavity in the back of the anode and 25.4 by 50.8 mm 1 by 2 inch stepped mounting hole provision through the center of the anode as shown in above referenced Figure 1. Install a polychloroprene or neoprene gasket material behind the button anode no less than 3.175 mm 1/8 inch thick by 203.2 mm 8 inch diameter. Use gasket adhesive consisting of 100 percent silicone waterproof caulking material similar to GE 100 percent Silicone Caulk suitable for continuous immersion service. Mold or fabricate plastic seal plugs from an approved polystyrene. Fabricate flanged sleeve from nascent oxygen and chlorine resistant rigid plastic material. Button anodes and assemble cable by the manufacturer.

2.5.5.3 Anodes Number

Provide the actual number high-silicon, cast-iron "button-type" anodes in accordance with the corrosion engineer's approved design calculations based on the system circuit resistance, current requirements, current distribution and anode life, in accordance with EM 1110-2-2704 and Appendix "A" in CERL Tech Rep FM-95/05, "Detailed Cathodic Protection Design Procedures for Pike Island Auxiliary Lock" as long as the minimum number of button anodes provided equals or exceeds one each for every 18.58 square meters 200 square feet of submerged steel surface area (for some typical anode configurations, refer to Figures 4, 5, 6, 7, C3, and F2 in CERL Tech Rep FM-95/05. The minimum number of anodes and an indication of their mounting locations should be shown in the design drawings.

2.5.5.4 Assembly

The manufacturer is responsible for assembling the conductor to the anode after the conductor has been tinned. Make connections with caulked tellurium lead, and then sealed with epoxy around the connection. Cover all tinned wire completely by lead. Reference Figure 1, "HSCBCI "Sausage" and "Button" Anode Designs of CERL Tech Rep FM-95/05 for mounting component details.

2.5.5.5 Impact Protection for Button Anode Cables

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NOTE: In areas with the problem of floating ice and/or driftwood, consideration should be given to the use of the more flexible ceramic coated titanium rod installed in PVC schedule 80 pipes with holes drilled in the pipe. These anodes should be used on the compartment side of the gate leaf, which is usually downstream. Alternatively, in areas subject to substantial floating ice and/or excessive driftwood, either Ceramic Coated Disk Anodes or High Silicon, Cast-Iron Button anodes may be used exclusively on both sides of the gate although this is usually a more expensive option.

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Weld a 152.4 mm 6 inch diameter by 203.2 8 inch long steel schedule-40 pipe with threaded pipe cap to the gate in back of each button anode. Drill a hole in the side of this pipe and weld a thread-o-let fitting to the 152.4 mm 6 inch diameter pipe at this point to receive the anode lead wire and conduit routed to the anode terminal box at the top of the gate leaf. The pipe and conduit are provided for impact protection of the anode cables and the anode bolt. Galvanize pipes and paint with 0.1778 mm 7 mil of paint.

2.5.6 Ceramic Coated Titanium Segmented Rod Anodes

a. Provide conductive ceramic coated titanium rods similar to that shown in Figure 3, "Typical Ceramic Coated Flat Disk Anode" of CERL Tech Rep FM-95/05. Provide anodes conforming to the requirements in Section 2.6.1 that are suitable for cathodic protection use, highly resistant to corrosion, and with good electrical properties. Each anode rod must be solid titanium and at least 3.175 mm 1/8 inch diameter by 1.2192 m 48 inch long with integral factory fabricated 12.7 mm 1/2 inch diameter ceramic coated titanium screw couplings at each end. Provide one anode for each assembled length with a screw coupled sealed PVC cable connector which is assembled by the manufacturer. Provide each such connector/cable assembly with sufficient lead length so that no splices are necessary between the anode/cable connector and the anode terminal box.

b. Provide the actual number of segmented rod assemblies and the number of strings per chamber in accordance with the corrosion engineer's approved design calculations based on the current required for protection in accordance with EM 1110-2-2704 and Appendix "A" in CERL Tech Rep FM-95/05, "Detailed Cathodic Protection Design Procedures for Pike Island Auxiliary Lock" as long as the number of segmented rod anode assemblies provided equals or exceeds 305 mm 1 linear foot of 3.175 mm 1/8 inch diameter (minimum) ceramic coated titanium rod material for each 9.29 square meters 100 square feet of submerged steel surface area and at least one full height assembly in each chamber (for some typical anode configurations, refer to Figures 4, 5, 6, 7, C3, and F2 in CERL Tech Rep FM-95/05). Extend each assembly at least 152.4 mm 6 inch above the normal highest water line to within 152.4 - 304.8 mm 6 - 12 inch of the bottom most girder plate.

2.5.7 Hi-Silicon Cast Iron Sausage Anode Strings

a. Provide high-silicon, cast-iron anodes consisting of an alloy of silicon, carbon, manganese, and iron conforming to ASTM A518/A518M. Ensure anodes are similar in all respect to the "Sausage" anode design shown in Figure 1, "HSCBCI "Sausage" and "Button" Anode Designs of CERL Tech Rep FM-95/05. Provide anodes that are suitable for cathodic protection use, are highly resistant to corrosion, and with good electrical properties. Provide "Sausage" anode castings with a nominal weight of 2.95 kg 6-1/2 lb each and with an irregular surface terminal connection cavity in the center interior of the tubular shaped anode as in CERL Tech Rep FM-95/05. Provide anodes that are 52.39 mm 2-3/16 inches in diameter by 305 mm 12 inch long, designed for tandem mounting in "link-sausage" manner on the anode lead cable. Connect cable and anodes all in a manner similar to the "Sausage" anode design shown in the above referenced Figure 1. Provide anode strings assembled by the manufacturer and do not splice the anode lead cable in the anode. Assemble anode by removing insulation from the anode cable and connecting the anode to the cable inside the anode.

b. Provide the actual number and spacing of the individual "sausage" segments and the number of strings per chamber in accordance with the corrosion engineer's approved design calculations based on the current required for protection in accordance with EM 1110-2-2704 and Appendix "A" in CERL Tech Rep FM-95/05, "Detailed Cathodic Protection Design Procedures for Pike Island Auxiliary Lock" as long as the number of "sausage" anodes provided equals or exceeds one each for every 18.59 square meters 200 square feet of submerged steel surface area and at least one string in each chamber (for some typical anode configurations, refer to Figures 4, 5, 6, 7, C3, and F2 in CERL Tech Rep FM-95/05). Extend each assembly from 152.4 mm 6 inch above the normal highest water line to within 152.4 - 304.8 mm 6 - 12 inches of the bottom most girder plate.

2.6 IMPACT PROTECTION FOR RODS AND SAUSAGE-STRING ANODES

2.6.1 PVC Pipe and Metal Couplings

Install PVC pipe, to be used for protection of the rod and sausage-string anodes, through each girder web in the center of each chamber which has an inside diameter (I.D.) that is at least 38.1 mm 1-1/2 inch greater than the anode outside diameter (O.D.). Provide pipe that is Schedule 80 PVC minimum and perforate on the side opposite the angle iron except for the area within 50.8 mm2 inch of the pipe couplings at each girder web. Ensure total open area provided by these perforations is at least equal to the surface area of the anode material contained within the PVC pipe. Install metal couplings through the girder webs on the compartment side of the gate (and where compartments are used on the skin plate side), where the PVC pipe penetrates the web. The steel coupling selected should have an I.D. that will allow the plastic pipe and its associated couplings to pass through the coupling. Align these steel couplings vertically for each anode string to serve as vertical troughs for the plastic pipes. Solvent weld full sections of the plastic pipe together end to end. Drill holes in the plastic pipe as shown on the drawings. Prepare steel coupling, angle iron, channel iron and all areas affected by the welding for painting and coat with the same paint system as the adjacent gate surfaces, in accordance with Section 09 97 02 PAINTING: HYDRAULIC STRUCTURES.

2.6.2 Protective Angle Irons

Submit anode disk, button, strip, rod and string details including ice and debris damage protection means for each anode type and alternative location.

2.6.2.1 PVC Piping

The protective PVC piping is subject to damage from floating ice and/or driftwood. Therefore, install protective angle irons in front of the protective PVC pipe. Ensure these angle iron sections are at least 6.35 mm 1/4 inch thick with angle legs whose height equals to at least 75 percent but no more than 100 percent of the plastic pipe coupling outside diameter. Weld this angle iron to each girder passage pipe coupling from the top of the highest girder to the bottom most girder plate. At each girder, which is penetrated by the PVC pipe, also weld the angle irons to the girder to reduce stress concentrations in the girder web caused by this penetration. Install entire assembly, consisting of the perforated PVC pipe containing the sausage anodes and the angle irons, as shown on the drawings. When plastic pipes only are used for sausage anode protection, ensure the girder penetration is the same, but install the angle iron in the impact area only.

2.6.2.2 Painting

Prepare steel couplings, angle iron, and channel iron for painting and coat with the same paint system as the adjacent gate surfaces, in accordance with Section 09 97 02 PAINTING: HYDRAULIC STRUCTURES. Each component must have the same minimum mil thickness (where 1 mil = 0.0254 mm 0.001 inch) of paint after couplings, angle irons, and channels are welded to the structure. Clean welded area to bare metal and paint in this same manner. Use paint that is the same type used on the lock gate.

2.7 MARKINGS

2.7.1 General

Accomplish markings, when required by the drawings and when specified herein, by means of metal or plastic sleeves as specified, stamped or engraved as indicated herein or on the drawings.

2.7.2 Rectifier Cabinets

Identify rectifier cabinets by means of suitable stainless steel plates attached to the outside of the rectifier cabinet by means of bolts or screws.

PART 3 EXECUTION

3.1 EXAMINATION

Visit the premises and thoroughly become familiar with all details of the work and working conditions, verify existing conditions in the field, note the exact locations for materials and equipment to be installed on the gates for cathodic protection, and advise the Contracting Officer of any discrepancies before performing any work.

3.2 INSTALLATION

Furnish all materials, equipment, and labor necessary to provide a complete and workable cathodic protection system conforming to the drawings and specifications. Provide all electrical work and materials conforming to NFPA 70 and requirements specified herein. Provide 150 mm 6 inchdiameter Schedule 40 steel pipe. Provide fittings for rigid metal conduit conforming to NEMA FB 1. Use straight conduit; no kinks or bends will be permitted. Ensure conduit is RGS except the 152.4 mm 6 inch pipe required for protecting the HSCI button anodes and PVC schedule-80 perforated protective pipe used to protect the ceramic rod and HSCI sausage string anodes.

3.3 WIRING

3.3.1 Gate Structure at Control Room

Install cables, of the type specified in paragraph DIRECT CURRENT CABLES, between the rectifier cabinet located in the control room and the dc receptacle located adjacent to each lock gate. Install this cable in conduit conforming to the requirements of paragraph CONDUIT AND FITTINGS.

3.3.2 Rectifier on the Lock Wall

Run Type SO cable exposed from the ac receptacle on the lock wall to the rectifier cabinet and from this cabinet to the dc receptacle. Also run Type SO cable exposed from the dc receptacle to the watertight bushing on the gate. Provide watertight insulating bushings with a cable seal fitting that makes a watertight conduit connection and a watertight seal between the cable jacket or insulation and the fitting. At all locations at which a conduit penetrates a watertight member, install a watertight packing gland constructed as shown on the drawings.

3.3.3 Wiring on the Gate Structure

Install all dc circuit wiring and anode lead wiring on the gate structures in rigid galvanized steel conduit, except install sausage anode strings as shown on the drawings and as specified. Where possible, install conduit on the gate structure in the recesses of the gate and flush with the wall skin plate to reduce the probability of physical damage from floating debris. Provide each anode with sufficient lead length, without splice, to reach the terminal cabinets located on the top of each gate leaf. Provide watertight insulating bushings with a cable seal fitting that seals between the cable jacket or insulation and the fitting. At all locations at which a conduit penetrates a watertight member, install a watertight packing gland constructed as shown on the drawings.

3.4 ROD AND SAUSAGE ANODE INSTALLATION

3.4.1 Metal Pipe Couplings for PVC Pipee

Weld metal pipe couplings (guides for PVC pipe used with sausage anodes) permanently on the gate structure. Do not use rod or Sausage-type anodes without these PVC pipe guides. Install PVC schedule-80 pipe (with holes) containing the sausage anode strings through the couplings with the holes oriented away from the protective steel angle channel (toward the back of the chambers). Use anode rod or string assembliescapable of being withdrawn at any time for inspection and repair. Install metal pipe couplings used for PVC pipe guides plumb, with an alignment tolerance of plus or minus 6.35 mm 1/4 inch over the entire height of the gate. When in place, weld the metal pipe couplings to the girder. Position protective angle irons at the previously specified locations to protect the PVC pipe and anode strings contained therein, exposing as much anode surface area as possible.

3.4.2 Assembly of Titanium Rod Anode

Sequentially assemble ceramic coated titanium rod anode as it is lowered into the PVC pipe by screw coupling each to the next anode element. Tighten coupling to a torque equal to that specified by the anode manufacture. Attach factory fabricated anode-to-cable connector to topmost element in a similar manner. The HSCI sausage anode assemblies are lowered into place inside the plastic pipe. Take care in handling these HSCI anode strings since the material is very brittle and subject to cracking if dropped or bounced against a hard surface. If any single anode element in the HSCI "sausage" string is cracked, replace the entire string with a new string. Do not install cracked anodes in the system. Install anode centering devices on each rod or string anode element to assure that the anode in maintained in a centered position within the pipe in a manner so that no portion of the anode is closer than 12.7 mm 1/2 inch of the pipe interior surface. Ensure each anode lead is continuous without splices from its point of connection to the anode to the terminal cabinet on the gate structure. Marj anode leads with anode string or anode number at the point of connection to the terminal box. Coil a minimum of 152.4 mm 6 inch of excess cable in the anode terminal box before cutting and connection the cable to the corresponding anode terminal in the terminal box. Coat this connection with a suitable oxidation preventing electrical contact paste.

3.4.3 Suspension of Anode Rod or String Assemblies

Provide support for each anode rod or string in a manner to permit easy raising, lowering, removal and/or reinstallation of the anode strings in the anode guides. Suspend anode assemblies from anode connecting cables using "Kellum" or equal grips to provide uniform and non-deforming gripping of the wire insulation.

3.5 DISK AND BUTTON ANODE INSTALLATION

3.5.1 General

Install the Disk or Button-type anodes at the locations shown on the approved Contractor's corrosion engineer design drawings.

3.5.2 Impact Protection Pipes Installation

Install impact protection pipes for the disk or button anode connection cables prior to installation of the anodes. Fully seal weld a 152.4 mm 6 inch diameter by 203.2 mm 8 inch long galvanized steel schedule-40 pipe with threaded pipe cap to the gate in back of each button anode. Drill a hole in the side of this pipe and weld a thread-o-let fitting to the 152.4 mm 6 inch diameter pipe at this point to receive the anode lead wire and conduit routed to the anode terminal box at the top of the gate leaf. The pipe and conduit provide impact protection of the anode cables and the anode support means. Prepare pipes for painting and coat with the same paint system as adjacent gate surfaces, in accordance with Section 09 97 02 PAINTING: HYDRAULIC STRUCTURES.

3.5.3 Disk Anode Installation

Deleiver the disk anode as a complete assembly by the manufacturer. Drill a 28.58 mm 1-1/8 inch diameter hole through the skin plate at each disk anode location shown on the approved system design drawings. Remove the FRP nut and washer from the disk support shaft. Apply 100 percent silicone waterproof caulk to the skin plate side of the anode composite shield in sufficient quantity to completely seal the shield at its outer perimeter and adjacent to the shaft where it passes through the skin plate. Then insert the disk through the gate skin plate and hold firmly in place while the washer and nut are placed on the support shaft from the opposite side of the gate and tighten using an automatic torque wrench set to 33.9 N-m 25 ft-lb of torque. Then attach cable connector to the integral threaded socket on the end of the anode support shaft and tighten to the torque specified by the manufacturer. Route this cable through the pipe protecting thread-o-let fitting and then via conduit to the anode terminal box. Ensure each disk anode lead is continuous without splices from its point of connection to the anode to the terminal cabinet on the gate structure. Mark anode leads with anode string or anode number at the point of connection to the terminal box. Coil a minimum of 152.4 mm 6 inch of excess cable in the anode terminal box before cutting and connection of the cable to the corresponding anode terminal in the terminal box. Coat this connection with a suitable oxidation preventing electrical contact paste.

3.5.4 Button Anode Installation

a. Provide polychloroprene or neoprene gasket material that is no less than 3 mm 1/8 inch in thickness and provide a minimum of 500,000 ohms of resistance between the button anode and gate. Furnish and install plastic plugs, molded or fabricated from an approved polystyrene to fit securely in the anode opening, in accordance with the approved submittal drawings. After assembly, insulate the anode support bolt completely on the button side of the gate by forcing epoxy cement through a passage provided for that purpose, around the insulating sleeve, into the bolt-head cavity, and out the vent hole in the plastic plug. Place the plastic plug in the bolt-head cavity such that the vent hole is at the highest point.

b. Provide epoxy cement of an approved type, with a suitable dielectric strength, that is water-resistant, and does not generate enough heat to damage or react with the plastic plug, the insulating bushings, or the gaskets. The epoxy must provide a minimum electrical resistance of 10 megohms between the anode and the gate.

c. Fabricate flanged sleeves from nylon conforming to the requirements of ASTM D789, or a similar approved rigid plastic material. It must be of proper size and length so that it will penetrate the skin plate enough to provide electrical isolation between the anode and skin plate. The sleeve must enter the skin plate at least 1.59 mm 3/16 inch. Refer to CERL Tech Rep FM-95/05 - Figure 1, "HSCBCI "Sausage" and "Button" Anode Designs for mounting component details.

d. Also isolate the bolt from the anode and skin plate. Use a metal washer behind the skin plate to connect the bolt to the gate so that the bolt will receive cathodic protection and not corrode. Apply the epoxy cement (resin) to provide a watertight seal in all areas of the bolt and anode bolt cavity. This will isolate the anode from the gate.

e. Sandblast the surfaces of the gates to be covered by the polychloroprene or neoprene gasket and the anode to clean metal to provide a bonding surface for the epoxy cement. The metal washer must not exceed the flange diameter of the nylon sleeve and the nylon flanges must be at least 3 mm 1/8 inch in diameter smaller than the diameter of the button anode hole bolt-head cavity. Provide anchoring bolt with slots that are large enough and adequate to transfer epoxy. Machine bolts and drill holes to transfer epoxy. Use bolt of sufficient length to allow threads to be visible past the nut. Consider structural thickness. Attach neoprene gasket to the gate and the anode using an approved cement to make a watertight seal. Use bolt to torque the anode to a watertight seal on the gate. Do not over-torque bolt, causing the metal anode to contact the gate or the polychloroprene gasket to turn out from the skin plate. Do not handle or carry anodes by the conductor. Ensure each anode lead is continuous without splices from its point of connection to the anode to the terminal cabinet on the gate structure. Mark anode leads with anode string or anode number at the point of connection to the terminal box. Coil a minimum of 152.4 mm 6 inch of excess cable in the anode terminal box before cutting and connection of the cable to the corresponding anode terminal in the terminal box. Coat this connection with a suitable oxidation preventing electrical contact paste.

3.6 RECTIFIER CABINET INSTALLATION

Secure wheeled rectifier cabinets, when provided, to the lock wall pipe rails using the clamp provided as a part of the rectifier. Secure stationary rectifier cabinets to the structures as shown on the approved submittal drawings.

3.7 RESISTOR AND ANODE TERMINAL CABINETS INSTALLATION

Install resistor and anode terminal cabinets at locations convenient for maintenance and testing purposes and to provide ready access to the terminals therein. Securely mount the cabinets to the gate structure with welded angle iron supports holding the cabinet in place.

3.8 REPAIR OF EXISTING WORK

Carefully lay work out in advance, and where cutting, channeling, chasing, or drilling of the gate structure or girder web, or other surfaces is necessary for the proper installation, support, or anchorage of the cabinets, conduit, raceways, or other electrical work, peerform this work carefully, and repair any damage to the gate structure or equipment by skilled mechanics of the trades involved, at no additional cost to the Government.

3.9 SYSTEM COMPONENT CIRCUIT RESISTANCE MEASUREMENT

Within 1 week following the filling of the lock, measure and record the resistance of each anode, reference electrode, system ground, and reference ground using four separate test lead wires and a Nilsson Model 400 AC impedance meter or other similar AC impedance instrument acceptable to the Contracting Officer. Make the measurement by disconnecting the component lead at the appropriate terminal in the terminal box and connecting two of the four AC impedance test leads individually to the lead wire. Connect the other two AC impedance test leads individually to the structure component to which the component is mounted or connected. Should the resistance between the lead wire and the structure (immerse anode and reference elements in water) be less than 50 percent or more than 200 percent of the calculated (expected) resistance, make the necessary corrections and/or modifications necessary to achieve the anticipated value(s).

3.10 STRUCTURE-TO-REFERENCE CELL POTENTIAL MEASUREMENTS

Following completion of the installation of the cathodic protection system and prior to placing the impressed current cathodic protection system in operation, make structure-to-reference cell potential measurements. Use testing equipment consisting of a calibrated copper-copper sulfate reference electrode with waterproof connector to insulated test lead wire suitable for immersion testing and of suitable length so that no splices are necessary in the test lead wire and a high-resistance digital voltmeter, Fluke Models 865 or 867 or equal. The copper-copper sulfate reference electrodes must contain a saturated reagent copper sulfate in distilled water. Prior to first system energization, record native "OFF" potential measurement using the same meter and calibrated reference electrode to be used during system energization and adjustment. Measure and record these native "OFF" potentials at all the specified locations.

3.11 RECTIFIER ADJUSTMENT

Accomplish rectifier adjustment as follows:

a. Adjust the output of the rectifier so that the gate-to-water potential measured using a reference cell indicates that the negative potential has stabilized and is at least minus 0.85 volt and not more than 1.2 volts. Make these measurements with current applied. Make corrections for IR drop. Accomplish this by adjusting the rectifier to obtain the aforementioned "instant-off" potentials. Make this IR drop correction by interrupting the current output of the rectifier either manually or automatically using a 90 percent minimum "ON" and 10 percent maximum "OFF". If more than one rectifier is energized at the same time, interrupt all such rectifiers simultaneously. The "OFF" time period must not exceed 1 second. During this "OFF" period, use the Fluke 865/867 meter to automatically read the minimum DC voltage that is the polarized protective potential on the gate.

b. Perform a complete structure-to-water potential survey of the gate leaf face.

3.11.1 Locations of Structure-to-Reference Cell

Locate the reference cell in the water, 12.7 to 76.2 mm 0.5 to 3 inch from the gate structures. Connect reference cell with a waterproof screw coupled connector to a conductor on a reel. Lower cell to depths in the water as indicated below. Connect reference cell conductor to the positive terminal of the digital voltmeter. Connect a second conductor from the gate structure to the voltmeter negative terminal. Repeat and record measurement procedure for each measurement location. Make measurements every 0.91 m 3 ft vertically (minimum) from normal pool elevation to the bottom of the gate. Make these same measurements at a minimum of five locations across the width of the gates on both the skin plate and chamber sides. In addition, make one set of measurements at the quoin end and one at the miter end on both sides of the gate. Mark all measurement positions permanently on the handrail of the gates directly above where the measurement is made.

3.11.2 Polarization Decay

a. Polarization decay measurements are only necessary if the gate surfaces adjacent to the sill plate, quoin and miter fail to meet the above criteria of providing negative protection potential of at least minus 0.85 volts.

b. Measure a minimum negative (cathodic) polarization voltage shift of 100 millivolts between the structure surface and the reference electrode cell above contacting the electrolyte. This polarization voltage shift is to be determined by interrupting the protective current and measuring the polarization decay. When the current is initially interrupted, an immediate voltage shift will occur. Use the second voltage reading displayed after the immediate shift as the base reading from which to measure polarization decay. Make polarization measurements at minimum 10-minute intervals for a maximum of 4 hours. This measurement cannot be made until the gate has had a chance to become polarized.

c. Location of the structure with respect to the reference cell for polarization decay measurements must be 0.305 m 1 ft from the bottom gate at the quoin, miter, and at 0.61 m 2 ft intervals along the bottom of the gate. Make measurements on each gate leaf face.

3.12 RECORDING OF MEASUREMENTS

Assemble all system component circuit resistances, structure-to-water potential measurements, including native potentials, in computer generated tabular form using Microsoft Excel or similar approved spreadsheet and submit six copies together with a copy of the data disk (3-1/2 inch floppy disks), with each location identified on the as-built drawings. Locate, correct, and report to the Contracting Officer any unusual data or problems encountered during checkout of the installed cathodic protection system. Structure-to-water potential measurements are required on structures as necessary to affirm that protection has been achieved on all submerged surface of the lock gates. Ensure all tests are witnessed by the Contracting Officer, and submit completed test measurements data for review and approval.

3.13 OPERATION AND MAINTENANCE INSTRUCTIONS

Submit Weekly, Monthly and Annual Test Procedure to be part of the operations and maintenance instruction manual. This test plan must conform to all applicable NACE International Recommended Practices.

3.13.1 Operating Instructions

Furnish to the Contracting Officer twelve (12) complete copies of operating instructions detailing the step-by-step procedures required for system start-up and adjustment of the rectifier to achieve the criteria of protection. Include native system and component test data (data before system energization), test set up, test equipment diagrams showing voltmeter and reference cell connections, test locations, and a description of the procedure for measuring "on" and "off" potentials. Provide detailed steps that show use of the equipment used in the training course and cover test and measurement of the cathodic protection systems for the gate leafs. Submit the Operation and Maintenance manual to the Contracting Officer for approval 30 days prior to the training course. Include the manufacturer's name, model number, service manual, parts list, and a brief description of all equipment and its basic operating features.

3.13.2 Maintenance Instructions

Furnish to the Contracting Officer eight complete copies of maintenance instructions listing routine maintenance procedures, possible breakdowns and repairs, and trouble-shooting guides. Include diagrams for the system as installed, instructions in making gate-to-reference electrode measurements, and frequency of monitoring.

3.14 TRAINING COURSE

Conduct a training course for operating staff, as designated by the Contracting Officer, on the cathodic protection system. The training period must consist of a total of 8 hours of training and must start after the system is functionally complete, but prior to final acceptance tests. Provide course material, including testing data and records, for a minimum of [12] [_____] Government attendees. Submit this course material to the Contracting Officer for approval 30 days prior to the scheduled start of the training course. Submit life of the anodes and outline of course and handout sheets with testing and measurements from the instruction manual and description of the use of equipment for completing test and measurements for students. Include demonstrations of the procedure for measuring the minus 850 millivolts "off" potentials and NACE International protection criteria of a minimum negative (cathodic) polarization voltage shift of 100 millivolts. Provide a digital voltmeter (Fluke 865 or similar and approved equal) and an insulated cable (minimum 30.48 m 100 ft length) on a reel with a saturated copper-copper sulfate reference cell attached by a factory assembled waterproof connector for these demonstrations. This equipment will become the property of the Government and turn over to the Contracting Officer upon completion of the training course.

-- End of Section --