Special Specification Item 4189
Cathodic Protection System

1. DESCRIPTION

Furnish all labor, tools, materials, equipment, and services necessary to install cathodic protection (CP) system (including bulk sacrificial anodes below mudline and distributed anodes inside the FRP encapsulation forms) and provide applicable connections and electrical work required for the function of the CP system. The CP system is to be installed as shown in the plans or as directed.

2. MATERIALS

2.1. General.

Furnish and install new materials. All equipment and materials supplied should be similar to that which has been in satisfactory service for at least 5 yrs.

Products must be produced by manufacturers regularly engaged in the manufacture of similar items.

The cost of all tests and analysis of the proposed substitute materials will be paid for by the Contractor. If the proposed substitutions require changes in the Contract Work, the Contractor will bear the costs related to such substitutions.

2.2. Bulk Anodes.

Provide materials specifically intended for bulk anode applications and 120 lb. minimum Al-Zn-In anode with the composition in accordance with Table 1.

Table1
Bulk Anode Composition

Element	Alloy %
Zinc (Zn)	2.80–6.50
Indium (In)	0.010–0.020
Silicon (Si)	0.08–0.2
Copper (Cu)	0.006 max.
Iron (Fe)	0.120 max.
Mercury (Hg)	--
Cadmium (Cd)	0.002 max.
Gallium	--
Others Each	0.02 max.
Others Total	0.05 max.
Aluminum	Balance

Provide anodes with a nominal size of 24 in. long, 7 in. wide, and 7 in. depth. Provide anode with geometric dimension not deviating by more than 10% and having the following galvanic properties in seawater shown in Table 2.

Table2
Anode Galvanic Properties

Property	Limit
Open Circuit Potential	1,100 mV (to Ag-AgCl ref.)

Efficiency	Min. 85%
Current Capacity	Min. 1150 Amp-hr./lb.
Consumption Rate -pounds/amp-yr	7.6 lb.

Provide mild steel eyebolt anode core steel material conforming to ASTM A36. Steel core dimensions will be as shown in the plans or as directed.

Provide documentation of approved quality assurance system and provide documentation of the anode manufacturing and testing process in accordance with NACE SP0387. Mark each anode and identify with the manufacturer's name, type of anode, and heat and sequence number. Mark all anodes (stamp) with heat and charge numbers and anode code (type of material). Package anodes in the manufacturer's plant in a package suitable both for lifting and transfer using a forklift, marine transportation, and long-term storage onsite.

Conduct factory tests and inspections as specified herein. Record the results of the tests and inspections and provide a certificate of conformity certifying that the anodes comply in all respects to the specifications. The anodes will not be approved by the Department unless all quality control documents and certificates were submitted to the Department in an orderly manner before shipment. As a minimum, conduct the following tests:

- visual inspection of cracks, surface irregularities, and straightness – 100% of total quantity according to NACE SP0387 for shrinkage, surface contamination, straightness, transverse and longitudinal cracks,
- random chemical analysis by spectrograph: Samples of each heat willl be taken for chemical analysis,
- weight test – 10% random selected of total quantity according to anode weight tolerance (each) - ±3%, and the total contract weight will not be below the nominal contract weight,
- dimensional inspection – 10% of total quantity according to anode mean length - ±3%, anode mean width - ±5%, and anode mean depth - ±10%, and
- samples of each heat will be taken for tests of anode material current capacity, closed-circuit potential and efficiency; NACE SP0387 and NACE TM0190.

The following manufactures are pre-approved for use on this project:

- Galvotec Alloys, Inc.
- Farwest Corrosion Control Company, and
- M&M Industries, Inc.

2.3. **Distributed Anodes.** Distributed galvanic units will be zinc with nominal exterior dimensions of approximately of 1 in. by 3 in. by length shown in the plans. The distributed anode unit will consist of 2 lb. of zinc per ft. of anode for anodes installed at splash zone and will consist of 1.2 lb of zinc per ft. of anode for anodes installed on tie beams above splash zone as shown in the plans. The zinc anode will be manufactured in compliance with ASTM B418 Type II.

The zinc will be alkali-activated with a pH greater than 14 and encased in an alkaline low resistance cementitious precast mortar and an internal alkaline-resistant reinforcing mesh that completely surrounds the zinc core. The anode unit will contain FRP reinforcing to resist expansion. The anode unit will not contain constituents that are corrosive to reinforcing steel such as chlorides, bromides, or other halides as per ACI 222R. The zinc will be uniformly distributed along the length of the anode unit.

The anode system will have a proven track record of the anode technology showing satisfactory field performance with a minimum of three projects of similar size and application.

The galvanic protection willl be Galvashield DAS distributed anode system by Vector Corrosion Technologies or approved equal.

2.4. **Anodes Wiring.** Supply bulk anodes with No. 6 AWG stranded copper wire with high molecular weight polyethylene (HMWPE) insulation brazed to a 1/2 in. diameter steel bar connected to steel eyebolt core as shown in the plans. Extend the anode wire from the point of connection to the anode to the associated junction box. Provide wire of sufficient length to avoid splicing wires.

Supply distributed anode units with a minimum of 2 integral 18-gauge grade 304 stainless steel wires of sufficient length to make connections between both adjacent anodes.

Provide be No.8 AWG stranded copper wire with red HMWPE insulation for anode header wire from distributed anodes to dedicated junction box. Provide wire of sufficient length to avoid splicing wires.

2.5. **Fasteners.** Provide Stainless Steel type 316 for all bolts, washers, anchors, and other fasteners used for installation of stainless steel angle, conduits, and junction boxes, unless otherwise specified in the plans or as directed. After installation, epoxy coat all bolts and fasteners with the Epoxy Coating per Section 2.17.

2.6. **Junction Boxes.** Provide 316 stainless steel NEMA Type 4X Junction boxes per the requirements of NEMA 250, with 14-gauge steel body. Size boxes as shown in the plans or as directed.

Provide hinges built of 316 stainless steel with stainless steel pin. Ensure a watertight seal. Furnish a neoprene gasket with the box and stainless steel lockable hasp. Provide externally mounted monitoring boxes as shown in the plans or as directed.

Label boxes with a black plastic tag bolted to the front panel of the box. Engrave tag in a color that contrasts with the identification of the box. Use minimum height lettering of 3/4 in.

Provide panel boards for junction boxes made of phenolic plastic 1/4 in. thick and sized as indicated. Install brass double nutted bolts, nuts and lock washers on the panel boards as indicated. Provide stainless steel hardware for mounting the panel board inside the junction box.

After installation, epoxy coat the junction boxes and hardware with the Epoxy Coating.

2.7. **Cable connection lugs.** Provide high conductivity high strength copper alloy such as Ilsco Type SLU, Ilsco Type CP, or approved equal. Aluminum or steel subcomponents are not permitted for cable connection lugs. Provide copper alloy for all current-carrying bolts and hardware.

2.8. **Shunts.** Provide shunts with resistance such that a 5 Amp current causes a voltage drop of 50 millivolts (i.e. 0.010 ohms). Provide 1/2 in. wide by 3-3/4 in. long flat manganin ribbon-style shunts such as Holloway Type JB.

2.9. **Buss Bars.** Provide copper buss bars (5 in. to 14 in. X 3/4 in. X 1/8 in.), and copper alloy bolts, nuts, and washers.

2.10. **Drain or Breather Plug.** Provide steel Universal Drain or Breather, 1/2 in, Raintight. Appleton ECDB50HP or approved equal.

2.11. **Diodes.** Install 8-Amp Solenoid Diode, with ring connectors at each end sized to fit connection bolts on the bus bar and shunt as shown in the plans or as directed.

2.12. **Negative Connections to the Reinforcement Wires.** Provide negative wires with single conductor, stranded copper, No. 8 AWG in size, with black HMWPE insulation and in colors as shown in the plans or as directed. Provide negative wires that are specifically designed for cathodic protection services and suitable for direct burial in corrosive soil, conforming to UL44. Wires with cut or damaged insulation will not be accepted and require replacement of the entire length of wire.

2.13. **Wire Identification Markers.** Code all wires with durable military grade, heat shrink labels with pertinent identification information as shown in the Plans and conforming to IEEE 323-2003, AMS-DTL-23053, MIL-M-

81531, and MIL-STD-883E. Apply markers to the wires at a minimum of 6 in. and no more, then 12 in. from the terminal connection end of the wire.

2.14. **Exothermic Weld Kits.** Wire-to-reinforcement connections are made by the exothermic welding process. Weld charges and mold size will be as specified by the manufacturer for various reinforcement sizes and surface configurations. Care should be taken during installation to be sure correct charges are used. Provide Cadweld as manufactured by Erico Products, Inc., Thermoweld as manufactured by Continental Industries, Inc., or equal. Use Duxseal packing as manufactured by Johns Manville or equal where necessary to prevent leakage of molten weld metal.

2.15. **Pin Brazing.** Provide pin brazing for connecting wires to structures in strict accordance with the manufacturer's recommendations. Make connections at locations indicated. Use an electric-arc silver soldering process specifically designed to minimize the pipeline heat effects associated with the wire connection process. Use a brazing gun ferule holder sized accordingly to accommodate the brazing pin and ferule. Use a direct-connect type brazing pin, with no threaded connections. Use a ceramic ferrule sized accordingly to accommodate the brazing pin. Use a brazed connection type for the wire lug; crimp lugs will not be allowed. Use pin brazing hardware and consumable material produced by a single manufacturer. Use "BAC Pin Brazing" by BAC Corrosion Control, or approved equal. Use wire lug type M1. Use "Direct Brazing pin, standard with fuse wire" type brazing pin for brazing No. 8 AWG wire and larger.

2.16. **L-shaped Stainless Steel Sections (Angle).** Secure anode wires, as shown in the Plans, within conduit bolted to a 6 in. by 6 in. by 3/8 in. coated stainless steel angle. Pre-drill the bolt holes on angle before coating. Provide a minimum of 3 additional anchoring holes to accommodate any location conflict with reinforcing steel. Shop coat the angle with the Epoxy Coating. Apply the epoxy and cure per the manufacturer's recommendations before transporting the assembly to the site.

2.17. **Epoxy Coating.** Coat welds, stainless steel L-shape section, hardware, connections points, and other areas specified with 100% solids, surface tolerant, fast cure epoxy for coating metal and concrete in wet or damp locations. Use A-788 Splash Zone Compound or approved equal. Surface preparation, application and quality control must be done per manufacturer's recommendations.

2.18. **PVC Conduit and Fittings.** Provide rigid PVC conduit and fittings conforming to the requirements of EPC-40-PVC conduit of NEMA TC 2 and fittings for EPC-40-PVC conduit of NEMA TC 3. Provide conduit and fittings that are UL 651 listed.

2.19. **Stainless Steel Conduits and Fittings.** Provide rigid Type 316 stainless steel schedule 40 conduits sized as shown in the plans.

2.20. **Concrete Repair Material.** Provide pre-approved concrete repair material in accordance with DMS-4655, *Concrete Repair Materials* for vertical or overhead repair.

2.21. **Delivery.** Deliver materials to the site in original containers and packaging with seals unbroken, labeled with manufacturer's name, product brand name and type, date of manufacture, lot number, directions for storing, and complete manufacturer's written instructions.

2.22. **Storage.** Store and handle materials in accordance with manufacturer's written instructions and safety requirements. Remove from site, and replace at no cost to Department, any materials that are damaged or otherwise negatively affected by not being stored or handled in accordance with manufacturer's written instructions. Store materials on land and transport to the site only the amount expected to be installed each day. Do not store materials on temporary structures on the water overnight.

2.23. **Replacement Anodes.** Furnish to the Department 10 anodes for future replacement needs.

3. EQUIPMENT

3.1. **General.** Provide all equipment required to perform the work. Not all the required equipment may be specified in this article. Quantities are not specified, and duplicate equipment may be necessary to perform the work.

3.2. **Concrete Reinforcing Steel Locator.** Electromagnetic or magnetic equipment capable of locating reinforcing steel within concrete.

3.3. **Multimeter.** True-RMS meter with minimum 10 MegOhm internal impedance capable of measuring voltage and resistance to a precision of 1 mV and 0.1 Ohms, respectively.

3.4. **Reference Electrode.** Silver-silver chloride reference electrode with a minimum diameter of 1 in. and a porous tip. The unit must be calibrated and stored in accordance with the manufacturer's instruction and verified against another reference electrode onsite.

3.5. **Resistance Meter.** Resistance meter with minimum of 200 mA test current and an input impedance of 10 MegOhm or more. The unit must be calibrated in accordance with the manufacturer's instruction and contain a calibration sticker.

3.5.1. **Concrete Removal and Repair Equipment.** Meet requirements of TxDOT Item 429, *Concrete Structure Repair*.

- Concrete coring equipment.
- Pneumatic chipping hammers nominal 15 lb. class or less.
- High-pressure, oil-free compressed air equipment capable of removing dust and dirt.
- Percussive or rotary drilling equipment for making holes in concrete substrate.
- Equipment for mixing and transporting concrete.
- Equipment for finishing of placed concrete.

4. CONSTRUCTION

4.1. **Submittals**

4.1.1. **Data Sheet.** Provide manufacturer's literature and technical data for each type of manufactured material and product indicated.

4.1.2. **Anode Factory Testing and Inspection Certification.** Provide anode factory testing and inspection certification.

4.1.3. **Quality Control Plan.** Provide a CP quality control plan with proposed testing means and methods, and sample data collection forms. The CP quality control plan will be authored by a NACE-certified cathodic protection specialist (CP-4).

4.1.4. **Shop Drawings.** Shop drawing details for electrical connections of bulk anodes. Provide proposed electrical connection details approved by the anode manufacturer. Include connections to bulk anodes, distributed anode assemblies, embedded reinforcing steel, and junction boxes.

- Include procedures to remove concrete for electrical connection and approved concrete repair material.
- Include mounting details for bulk anodes, distributed anode assemblies, wiring, and junction boxes.

4.1.5. **Electrical Continuity Report.** Provide the test results for electrical continuity testing of reinforcement, and negative and anode wires continuity before and after concrete placement. The electrical continuity report will be authored by a NACE-certified cathodic protection specialist (CP-4).

4.1.6. **Cathodic Protection System Activation Report.** Provide cathodic protection report authored by a NACE-certified cathodic protection specialist (CP-4).

4.2. **Field Quality Control.** Engage a NACE-qualified cathodic protection technician (CP-2 qualification or higher) to confirm electrical continuity testing of reinforcement, negative and anodes wires continuity before and after concrete placement. Test cathodic protection system before and after activation. The electrical continuity report, CP quality control and activation report will be authored by a NACE-certified cathodic protection specialist (CP-4). The CP quality control and testing plan will be signed by the CP-4. Submit CP quality control and testing plan for Engineer review.

4.3. **Surface Preparation.** See Special Specification 4188, "FRP Encapsulation System" for surface preparation requirements for concrete beneath FRP encapsulation form before installation of distributed anodes. Concrete surface area for the installation of the bulk anode will be cleaned by abrasive blasting, water blasting or other means to remove all marine growth to allow installation of the bulk anode.

4.4. **Exposed Conduit Assemblies.** Shop-coat new stainless steel sections with the Epoxy Coating. Submit product data sheets and obtain approval of paint system before performing the work.

4.5. **Installation of Bulk Anode Assemblies.** Install anodes in accordance with recommendations of anode manufacturer at locations specified in the plans.

- Place anodes adjacent to footing or piles at a minimum depth of 2 ft. below mud line. The contractor will be responsible for all the necessary surveying to determine the mud line elevations. Place anodes horizontally and offset from the footing or pile by 2 ft. as shown in the plans or as directed.
- Place the stainless steel angle just below the bottom of the FRP and extend 2 ft. below the mudline, unless FRP form extends to the mudline. In that case, install the stainless steel angle on the FRP form in dry condition and patch the anchor holes per FRP manufacture's recommendations.
- Extend anode wires from the anode up through conduit mounted on the stainless steel angle, up under the FRP to the associated junction box. Where the wires exit the FRP the wires will be placed inside the stainless steel conduit. Terminate the conduit at the appropriate junction box.
- Place the wires in conduit at all locations where the wires are exposed and not under the FRP. Extend the conduits a minimum of 6 in. beneath the FRP.
- Using a portable silver-silver chloride reference electrode measure and record each anode's potential to earth using the anode wire. The measured potential threshold indicating that the anode wire is installed properly and the anode is functional will be -1100 mV. Remove and replace all anodes that do not meet the threshold.

4.6. **Installation of Distributed Anode Assemblies.** Install anode assemblies in accordance with recommendations of the anode manufacturer at locations specified in the plans or as directed.

Install disturbed zinc anodes beneath FRP encapsulation forms at elevations shown in the plans. Attach the anodes to the existing surface of concrete using concrete anchors per the manufacturer's recommendations. Install distributed galvanic anode units with an even spacing around the concrete surface. Secure the anodes against 1/2 in. or larger spacers to allow consolidation of the concrete around the anode.

At each pier and bent connect all anode cores together using pre-fabricated anode wires (2 per anode). Route each wire in opposite directions and tie into the adjacent anode wire as shown in the plans.

Attach the anode header wire to the stainless steel wire via split-bolt. Encapsulate the split bolt with Epoxy Coating after assembly and verification of wire electrical continuity. The number of anode header locations per anode assembly as shown on the plans. Install the anode headers at even spacing where more than one anode header is specified for an anode assembly.

Route the anode header wires up through conduit mounted on the stainless steel angle, up under the FRP to the associated junction box. Where the wires exit the FRP the wires will be placed inside the stainless steel conduit. Terminate the conduit at the appropriate junction box.

Place the wires in the conduit at all locations where the wires are exposed and not under the FRP. Extend the conduits a minimum of 6 in. beneath the FRP.

For grout or concrete mix used to fill the annulus between the existing concrete surface and the FRP encapsulation see Special Specification 4188, "FRP Encapsulation System."

4.7. **Junction Boxes (Test stations).** Construct junction boxes (test stations) as shown in the plans.

- Install junction boxes at the locations shown in the plans. Install the bottom of the junction box a minimum of 5 ft. above the finished top of the footing. Place all exposed negative and anode wire runs in stainless steel conduit as shown in the plans.
- Anchor the junction box to the concrete column using four stainless steel anchor bolts.
- Route negative and anode wires, and terminate them in the appropriate junction boxes as shown in the plans. Leave a minimum of 24 in. of extra wire in its terminus in each box.
- Place wire identifiers on all wires before backfill or encasement, and installation of junction box.
- Connect negative wires to one of the three buss bars. Connect the anode wires to the other two buss bars. Leave the shunts disconnected until the CP system is ready for activation.
- After installation, test all wire connections at the junction box to ensure that they meet the requirements of the specification.

4.8. **Connection to Rebar (Negative Connection).** After exposing reinforcing bars, verifying electrical continuity of steel bars, and abrasive blasting to SSPC-SP10 (Near White Metal), connect a No. 8 AWG copper wire with black HMWPE insulation to exposed steel. Make the connection by pin brazing the wire directly to the rebar or exothermically welding the wire to a bond plate that is welded to the rebar as shown in the plans. Make the number of negative connections as shown in the plans. Coat all welded and pin brazed connection points using the Epoxy Coating.

- Using a portable silver-silver chloride reference electrode measure and record the steel bar's potential to earth and the end of the negative wire connection (the end that will terminate in the junction box) to earth. To indicate electrical continuity the two potentials must not vary by more than 5 mV.
- Wire placement: Extend negative wires from the point of connection through conduit, up under the FRP to the associated junction box. Where the wires exit the FRP, place the wires inside a Schedule 40 stainless steel conduit per this specification item.
- Concrete restoration: After connection to rebar is made, repair concrete area per the *TxDOT Concrete Repair Manual*. Abrasive blast the exposed reinforcing steel before patching and use approved bonding agent products.

4.9. **Cathodic Protection Testing.** Test the wires and potentials before and after activation of the cathodic protection system per NACE SP0408. If the measurements do not meet the stated criteria stated in this document determine the causes and conduct repairs, at Contractor's expense.

- When all construction is completed and before connection the anode wires to the associated buss bar remeasure the anode-to-earth potential to a fixed-location using a portable silver-silver chloride reference electrode. To indicate anode wire is installed properly and the anode is functional the potential measured must be -1100 mV.
- When all construction is completed and before connecting the negative wires to the associated buss bar re-measure the negative wire-to-earth potential at a minimum of two locations per bent or pier. Negative wire potential will be compared to pre-burial or encasement measurement (keeping the reference electrode at the same location for both sets of measurements). The potentials will be within 5 mV of each other. Record these values as the Native negative potentials.

- Once the negative and anode wires have passed the potential measurement tests above then connect the wires to the appropriate buss bar. Install the 0.01 Ohm shunt and diode as shown in the plans. Connect the three buss bars together through the shunts and let the CP system polarize.
- Measure and record the On and Instant Off negative wire-to-earth potentials using the portable silver-silver chloride reference electrode placed at the same locations as when the Native negative potentials were measured.
- Measure and record the current output across the shunt.
- The criteria used to indicate adequate corrosion protection of reinforcing steel will be per NACE Standard SP0408.

Present all test data in the Cathodic Protection System Activation Report authored by the NACE-certified cathodic protection specialist (CP-4). Report all deficiencies found in the CP system. Include a statement on the functionality of the CP system in relation to criteria. The report must be signed by the CP-4. Submit the report to the Engineer for acceptance and approval.

4.10. **Rebar Electrical Continuity Testing.** Test the electrical continuity between reinforcing bars in all cathodically protected areas (a minimum of 5 locations per 100 sq. ft.) by an alternative direct current reverse polarity resistance testing and potential measurement testing with a fixed location reference electrode per ISO 12696 as specified below. If the criteria are not met, the electrical continuity is not met and additional provisions such as adding bond wires or rebar welding will be required to restore electrical continuity at Contractor's expense. To be considered electrically continuous, all steel elements must meet the following criteria:

- an individual stable resistance reading less than 1 Ohm, or
- resistance reading that do not change by more than 0.1 Ohm when the polarity of the instrument lead is reversed, or
- a stable potential measurement with a difference of 1 mV or less between all rebar where reference electrode is placed at a fixed location in soil.

Present all test data in the Electrical Continuity Report authored by the NACE-certified cathodic protection specialist (CP-4). The report must be signed by the CP-4. Submit the report to the Engineer for acceptance and approval.

5. MEASUREMENT

This Item will be measured as Lump Sum.

6. PAYMENT

The work performed and the materials furnished in accordance with this Item and measured under "Measurement" will be paid for at the unit price bid for "Cathodic Protection System". This price is full compensation for providing and installing anodes, electrical continuity, wiring and associated hardware, electrical testing, replacement anodes, and for tools, labor, equipment, and incidentals.